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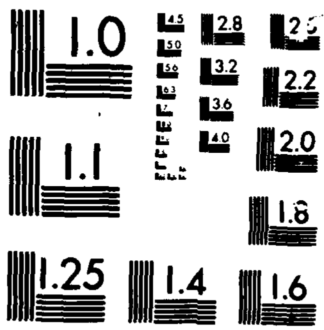

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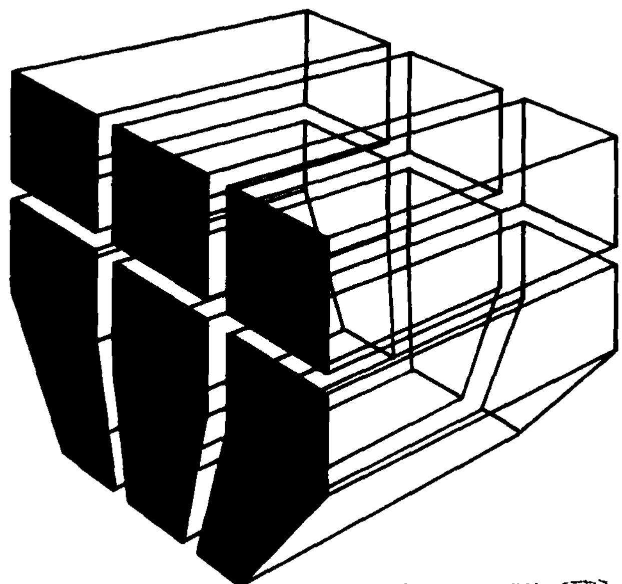
US Army Corps
of Engineers
Construction Engineering
Research Laboratory

TECHNICAL REPORT M-86/04
March 1986

AD-A167 312

The Practical Use of PAVER in Planning, Programming, and Developing Projects for Pavement Maintenance and Repair

by
D. R. Uzarski
R. C. Soule



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This report provides step-by-step procedures on how to successfully implement PAVER, and explains how to use the system for network and project-level pavement management activities and related facilities engineering duties. The report is organized in the sequence that most pavement engineers/managers would perform their pavement management tasks.

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The PAVER pavement maintenance management system is becoming widely used throughout military and civilian communities. The PAVER system provides to the facilities or public works manager a very powerful tool for planning, programming, and developing projects for annual and long-range pavement maintenance and repair.

This report provides step-by-step procedures on how to successfully implement PAVER, and explains how to use the system for network and project-level pavement

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management activities and related facilities engineering duties. The report is organized in the sequence that most pavement engineers/managers would perform their pavement management tasks.

FOREWORD

This research was conducted for the Office of the Assistant Chief of Engineers (OACE) under Operations and Maintenance, Army Funding Authorization Document 2-0000-79, dated October 1984, "PAVER Technology Transfer." The work was conducted by the Engineering and Materials Division (EM), U.S. Army Construction Engineering Research Laboratory (USA-CERL). The OACE Technical Monitor was Mr. Robert Williams (DAEN-ZCF-B).

The contributions of Mr. R. Rice and Mr. J. Zamarron (Engineer Activity, Capital Area), Mrs. Rachel Dyal, Ms. Terry James, (USA-CERL), and Mr. Robert Williams (DAEN-ZCF-B) are gratefully acknowledged. A special acknowledgment is extended to Dr. M. Y. Shahin for his development and continued refinement of the PAVER system, without which this report would not be possible. The review comments of Dr. M. Y. Shahin, Ms. K. Cation and Dr. E. S. Dierenfeld (USA-CERL), Mr. P. Styer (FESA), Mr. T. Bruder (U.S. Navy, Southern Division, NAVFAC), Mr. R. Henderson (U.S. Navy, PWC, San Diego), Mr. H. G. Patel (FEA, Korea), Mr. S. D. Kohn (USAWES), Mr. F. W. B. Taylor (FORSCOM), and personnel from HQ, U.S. Army Western Command (Fort Shafter, HI), and U.S. Army Information Systems Command (Fort Huachuca, AZ) are also gratefully acknowledged.

Dr. R. Quattrone is Chief of USA-CERL-EM. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director.

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THE PRACTICAL USE OF PAVER IN PLANNING, PROGRAMMING, AND DEVELOPING PROJECTS FOR PAVEMENT MAINTENANCE AND REPAIR

1 INTRODUCTION

Background

The PAVER pavement maintenance management system, developed by the U.S. Army Construction Engineering Research Laboratory (USA-CERL),[1] has been gaining widespread acceptance throughout the military and civilian communities since its general introduction in 1980. PAVER has been shown to be an extremely valuable management tool, when properly implemented and used. To ensure successful use of the system, users are strongly encouraged to obtain and read all available PAVER literature, especially the *PAVER User's Guide*, *PAVER Reference Manual*, TM 5-623 or USA-CERL Technical Report M-294, USA-CERL Technical Report M-310, and Air Force Regulation (AFR) 93-5, and to obtain training, both in the various PAVER elements and in pavement maintenance management.

So far, most of the PAVER literature has focused on the system's mechanics and outputs as well as pavement maintenance management concepts. However, there is a need for a definitive manual, geared toward the Directorate of Engineering and Housing (DEH) staff, on how to use the PAVER outputs in the management activities of planning, programming, and developing projects for annual and long-range pavement maintenance and repair.

Objective

The objectives of this report are to (1) provide step-by-step procedures on how to successfully implement the PAVER system and (2) explain how to use PAVER in the daily activities of pavement management and in related facilities engineering duties.

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[1] M. Y. Shahin and S. D. Kohn, *Pavement Maintenance Management for Roads and Parking Lots*, Technical Report M-294/ADA110296 (U.S. Army Construction Engineering Research Laboatory [USA-CERL], 1981); M. Y. Shahin and S. D. Kohn, *Overview of the 'PAVER' Pavement Management System and Economic Analysis of Field Implementing the 'PAVER' Pavement Management System*, Technical Manuscript M-310/ADA116311 (USA-CERL, 1982); M. Y. Shahin, *Pavement Management, the PAVER System: User's Guide*, ADP Manual 356-1 (Facilities Engineering Support Agency [FESA], 1985); M. Y. Shahin, *PAVER Reference Manual*, Draft ADP Document (FESA); M. Y. Shahin, M. I. Darter, and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol V*: Proposed Revision of Chapter 3, AFR 93-5, CEEDO-TR-77-4 (CEEDO, October 1977); M. Y. Shahin, S. D. Kohn, R. L. Lytton, and E. J. Japel, *Development of a Pavement Maintenance Management System, Vol VIII: Development of an Airfield Pavement Maintenance and Repair Consequence System*, Technical Report ESL-TR-81-19/ADA114805 (Air Force Engineering Services Laboratory, 1982); Technical Manual (TM) 5-623, *Pavement Maintenance Management* (Department of the Army [DA], November 1982); Air Force Requlation 93-5, *Airfield Pavement Evaluation Program* (Department of the Air Force, 18 May 1981).

Approach

Information was obtained from military engineers having detailed knowledge of and field experience with actually managing pavement networks with the PAVER system. The figures, tables, and computer reports provided for illustration reflect actual procedures and data used at military installations. The sequence in which various topics discussed in this report are presented is the sequence in which these tasks would most likely occur in an actual application. Also, as an easy reference for all PAVER reports, Appendix A presents the PAVER Outline report that summarizes all of the other reports. The information in this report will address only part B of the PAVER outline.

Scope

This report is not intended to duplicate documentation already provided in the references listed in Footnote 1; however, certain key points are emphasized. It is assumed that the user is already familiar with the information in those documents.

Mode of Technology Transfer

PAVER has potential application in both the military and civilian communities. Therefore, it is recommended that the information in this report be incorporated into a tri-services manual for the military's use and provided to the American Public Works Association for distribution to the civilian community. Because of the dynamic nature of the PAVER research and development program, certain features of this report will become obsolete as refinements are added to the system. Therefore, the user is encouraged to refer to the PAVER User's Guide for dynamic changes. It is also recommended that this report be updated periodically to reflect changes and improvements resulting from research and field experience.

2 IMPLEMENTING PAVER

Before PAVER can be used, it must be implemented at the installation. Implementation involves a systematic procedure for obtaining the data to be ·sed in the PAVER database, establishing local operating procedures, and ensuring that personnel are proficient in PAVER use. The implementation must be well planned. Appropriate personnel must be trained, and they must study both PAVER and general pavement maintenance management reference material. If planning is inadequate, a trouble-plagued implementation may result, and people may not accept and use the system.

Level of Implementation

PAVER can be implemented at various levels, ranging from a manual system with very limited data for just a few pavements to a computer-based system for all pavements with large amounts and types of data. The appropriate level must be determined during the preliminary planning phase of the implementation. Several factors must be considered, including available funds; type, amount, and condition of the pavements in the network; availability of skilled and trained personnel to implement and operate PAVER; and access to and level of computer support.

General Procedures

Implementation Time

The implementation process will take several weeks or months. The three most critical variables that will ultimately determine the length of time required are method of implementation, amount of the pavement network to be included at a given time, and amount of pavement information to be collected.

Implementation Methods

The implementation process is labor-intensive. The needed manpower can come from a contractor, from in-house, or a combination of the two. Contracting is the most common method for military installations.

Contracting has been very successful and offers several advantages. The contractor provides the resources for collecting the data, and also ensures that it has been properly coded into the database. Getting initial data loaded can be troublesome, so having a knowledgeable contractor perform that task can save many hours of frustration. Also, the contractor can provide expertise regarding the implementation, whereas inexperienced installation personnel can easily waste effort and make some inappropriate assumptions. A knowledgeable, experienced contractor can work very effectively and efficiently and can provide on-site training to the appropriate personnel. If desired, the contractor can begin some of the management activities, thereby providing a starting point for installation personnel to continue system management.

If the work is done by contract, it should be performed by a reputable engineering firm that is knowledgeable in pavements. The preferred contract type is an open-ended architect and engineering (A&E) or engineering services (ES) contract, which permits selection based on qualifications. Once the contractor is selected, a fee is negotiated.

One disadvantage of contracting is that it may take several weeks or months to get a contract prepared, advertised, negotiated, and awarded. This lengthens the implementation period. A second disadvantage is that contractor implementation will be more costly than in-house implementation. However, considering the scope of services that a contractor can provide, the extra cost may be well worth it. For contractor implementations, it is strongly recommended that a person designated from the installation be thoroughly involved throughout the implementations. If the installation is not involved with the contractor, the entire contracted effort could be wasted.

In-house implementations can be very successful, especially if the amount of pavement to be implemented is very small. If enough personnel are available, knowledgeable, adequately trained, and receive the close supervision required, the implementation will be successful. In most cases, temporary personnel will be needed to collect much of the data. Summer-hire college students can provide an excellent workforce.

A combination implementation may be best for ensuring a relatively trouble-free implementation and a smooth transition to using PAVER. In this method, contractor personnel collect, prepare, and load certain data elements, and in-house personnel do the rest. Deciding who does specific activities is subject to local planning. Pavement condition survey work is the most labor-intensive activity of the implementation and is easily contracted. Any activity that cannot be competently accomplished in-house should be contracted.

Phasing the Implementation

Unless the amount of pavement in the network is very small, it is advantageous to divide the implementation into phases. This simply involves dividing the network into logical groupings, such as branch use (roadway, runway, etc.), pavement rank, geography, condition, etc., and performing the implementation activities for each phase, one at a time. There is a steep learning curve associated with implementing PAVER, and lessons learned in implementing one phase will carry over to follow-on phases. Also, by phasing the implementation, management activities can begin on phases that have been implemented. This allows PAVER to become useful as soon as possible.

Amount of Data To Collect

It is a fallacy that large amounts of data must be collected to properly manage a pavement network. Specific data needed to use PAVER in managing the pavement network at both the network and project levels are discussed in Chapters 3 and 4. Also, it must be recognized that considerable manpower and dollar resources can be spent to collect unnecessary data. Therefore, collecting too much or the wrong kind of data will only increase the time and cost of implementation. The user must always remain sensitive to this issue when planning for and implementing PAVER. Management needs at the appropriate level should mandate the data requirements.

Activity Personnel Involvement

Regardless of the implementation method, key personnel must become involved to some degree. Also, one person should be designated as the PAVER manager/coordinator. Frequent progress reviews and approvals of the contractor's work are essential to keep personnel involved and to ensure that the contractor is progressing satisfactorily. Having the contractor provide essential training is another means of involvement. It is imperative that the users understand what the implementation has accomplished and

what information is available in the database so that they will accept and use the system. Experience has shown that lack of participation during implementation can lead to lack of acceptance and confidence when the system becomes operational. As a result, the system will ultimately fall into disuse.

Training

All personnel who will interface with PAVER either directly or indirectly must be trained, because training is essential to the system's and management's success. Attendance at a formal PAVER course is recommended for key personnel, and one or two should attend before any formal implementation plans are made. Training on certain PAVER skills, such as standardized inspection procedures, is provided easily by a contractor. Other skills, such as report generation, are best done "on the job" through dedicated practice sessions under the supervision of knowledgeable personnel.

FESA Involvement

The Facility Engineering Support Agency (FESA) is the field user's link to the PAVER system. FESA must be contacted to establish a computer account and also serves as the technical point of contact if problems develop and assistance is needed. FESA will provide contract implementation guide specifications, examples of implementation contracts, manuals, a list of trained and experienced contractors who can help with implementation, the latest information regarding implementation costs, a PAVER training course schedule, and an implementation guide.

Implementation Process Steps

Thirteen distinct and independent steps are required for any successful Pavement Management System development and implementations.[2] When applied to PAVER, these steps have been modified somewhat based on the experience of existing PAVER users and if not followed, can lead to significant and costly problems. Generally, the steps follow in a logical progression; however, certain steps may occur at any time, and some can run concurrently. The steps are listed below and discussed in detail in the following sections of this chapter.

1. Decision to start

2. Commitment from top management

3. Development of preliminary work plan

4. Establishment of steering committee

5. Development of detailed work plan

6. Determining requirements for and obtaining computer hardware and software

7. Development of a preliminary system

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[2]*Pavement Management: Proceedings of National Workshops* (Federal Highway Administration, 1981).

8. Testing and verification

9. Demonstration of the system

10. Establishment of Pavement Management System location within the organization

11. Full-scale implementation

12. Routine operation

13. Maintenance and improvement of the database.

Step 1—Decision To Start

As simple as this step is, it may be the most important step of all, and should not be taken prematurely. It should occur only when the user/manager is convinced that benefits can be gained by implementing PAVER. The lack of a commitment by a prospective user at this stage could lead to problems in implementing and in using PAVER in general.

Step 2—Commitment From Top Management

It is essential to obtain commitment to the PAVER system and pavement maintenance management in general from all management personnel who will make decisions based on the information or analyses it provides. There are several reasons for this. First, to implement and operate PAVER, time and money must be devoted to the project, both for one-time implementation costs and for subsequent annual operating costs. A commitment to allocate resources is essential to continued success. Second, and most important, since implementing PAVER constitutes a commitment to a management system, all levels of management must ensure that it is being used effectively. This often means that various policies and procedures used to make maintenance decisions must be revised to accommodate the system. PAVER will have to be effectively integrated into current facilities management activities. This integration is as critical to the implementation as establishment of the PAVER database. Someone in the local organization must be designated by top management as a PAVER manager/coordinator. This person should ensure that there is proper office coordination with PAVER, that the database is kept current, that information within the database is accurate, and act as the installation point of contact with FESA. The installation pavement engineer is the logical person for this task. Local computer support services (in-house or contract) must be obtained and committed to keeping the local operation serviceable. Without top management commitment, local use of PAVER can fall into disarray and the database can become obsolete.

Step 3—Development of Preliminary Work Plan

The first element of this step is to establish a local PAVER User's Group. The size of this group depends totally on the size of the local organization, but it should include representatives from the various departments, divisions, or offices that will integrate PAVER into their management activities. One representative from each of these units is appropriate, and the PAVER manager/coordinator should serve as chairman. The main

purpose of this group is to plan the implementation; however, it will also serve in a post-implementation capacity and to coordinate use, resolve use problems, and provide feedback for improvements.

It is also useful at this stage to obtain outside help in planning the implementation. If FESA has not yet been contacted, this should be done to establish computer accounts, obtain sample contracts (if necessary), and gather data regarding implementation costs. Other installations can be contacted about their PAVER implementation experience. Information should be gathered from FESA and other installations about the contractors who have implemented PAVER and the quality of their work. Many installations are willing to share lessons learned with installations who are just beginning implementation. Capitalizing on this information can be very valuable in avoiding costly mistakes. Help can also be obtained from a formal training course on PAVER, several of which are offered annually. (FESA can provide the schedule.)

The preliminary work plan must outline the objectives associated with implementation. The objectives should consist of determining how many phases there will be in the implementation, what pavements constitute each phase, and what milestones should be established for completing each phase. The method of accomplishment must be established during this stage, along with a cost estimate. The size of each phase should correspond to funding availability. Regardless of the amount of funds initially available, it is recommended that the initial phase (Phase I) be limited to no more than about 10 lane miles of pavement.

It should also be decided if the contractor (if applicable) will prepare a preliminary annual and/or long-range maintenance/repair plan for the sections implemented.

Step 4—Establishment of Steering Committee

The steering committee is independent of the local user's group and should be made up of senior facilities management personnel at the installation. The members and size of the steering committee depend on the organization; an example would be the department or division heads of the personnel serving on the user's group. The Director of Engineering and Housing (DEH) or the deputy DEH would be a likely candidate for chairman. It is also appropriate that a member of the user's group, preferably the PAVER manager/coordinator, also serve on this committee as a liaison.

The purpose of this committee is to provide guidance to and oversee the user's group on the implementation plan and to help resolve planning or implementation problems. The committee will also give final approval of the plan. Another essential purpose of the steering committee is to ensure that the senior civilian and military managers who make maintenance policy and establish work procedures are fully apprised of the PAVER implementation. Establishment of the steering committee and the overall commitment to PAVER maintenance management from top management are very interrelated--one reinforces the other.

Step 5—Development of Detailed Work Plan

This step is a refinement and expansion of the preliminary plan established in step 3. A rough determination should be made of how many pavement sections will be created during the implementation. This can be done by studying the installation map and by using basic knowledge of pavement types and traffic patterns. The network definition procedures as described in Air Force Regulation 93-5 for airfields and TM 5-623 (or USA-CERL Technical Report M-294) for roads and streets should be studied at this point. The

pavement section will constitute a relatively uniform pavement area, and it represents the smallest portion of the network that will be managed individually. Since the network is really a group of pavement sections, the number of pavement sections that will be created is important from a management perspective. There are no hard and fast rules, only guidelines that govern the creation of a section, so size should be considered from a practical management perspective. Ultimately, maintenance and repair must be done to any given section, and the work should pertain to the *entire* section. Thus, a small number of very large sections or large numbers of very small sections would not be practical since that would only increase the management burden. Also, implementation and operating costs depend on the number of sections in the network, since creating and updating the database is on a section-by-section basis. Figure 1 shows an example[3] for planning purposes, of a section layout in conjunction with the overall pavement network. The actual section creation and network map preparation are done in a later step.

Three specific features of PAVER should be studied at this stage for use in the implementation, where applicable: use of zones, section categories, and the particular method for computer coding branch name and number. These three features provide powerful tools for storing and manipulating of specific PAVER information for management purposes.

Zones designate geographic portions of the network and are particularly useful for showing remote sites that are to be incorporated into a larger network. Zones will allow network-level management activities to be done quickly and efficiently at the sub-network level.

The use of section categories permits each section to be designated with an appropriate alphanumeric code. Thus, specific sections can be grouped under categories chosen by the manager. Examples would be the designation of specific pavement sections to snow routes, maintenance funding categories, or any other category of interest.

Branch numbers should be thought out carefully to avoid confusion later. This can generally be done in any manner, provided the number is alphanumeric and does not exceed five characters. Most typically, the first character would be the same for similar types of pavements, such as roadway, runway, apron, etc. Any number or letter can be used as long as it is applied consistently to a given type of pavement. To facilitate system use, the remaining four characters normally describe the pavement name. Examples include: IOHIO, Ohio Street; P1600, parking lot by Building 1600; R59W, runway 59 west. It is not necessary to use all five alphanumeric characters in the branch number. Section numbers are also alphanumeric and two characters are permitted. Both characters should *always* be used in the designation. Examples include 01, 1N, 1S, 02, 03, etc. Sections should be laid out and numbered consecutively (Figure 1).

It must also be decided how the sections and sample units, if desired, will be marked in the field. Methods that have been used include paint, monuments, brass disks embedded in curbs and/or pavement, and nails with washers pounded into the pavement. There is no best method, since each has advantages and disadvantages, so local judgment must be used. It is recommended that as a minimum, section boundaries be marked.

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[3]R. E. Smith, M. I. Darter, T. R. Zimmer, and S. H. Carpenter, *Implementation of the PAVER Pavement Management System and Development of the Maintenance and Repair Plan*, Final Report (U.S. Navy, Great Lakes, IL, 1983).

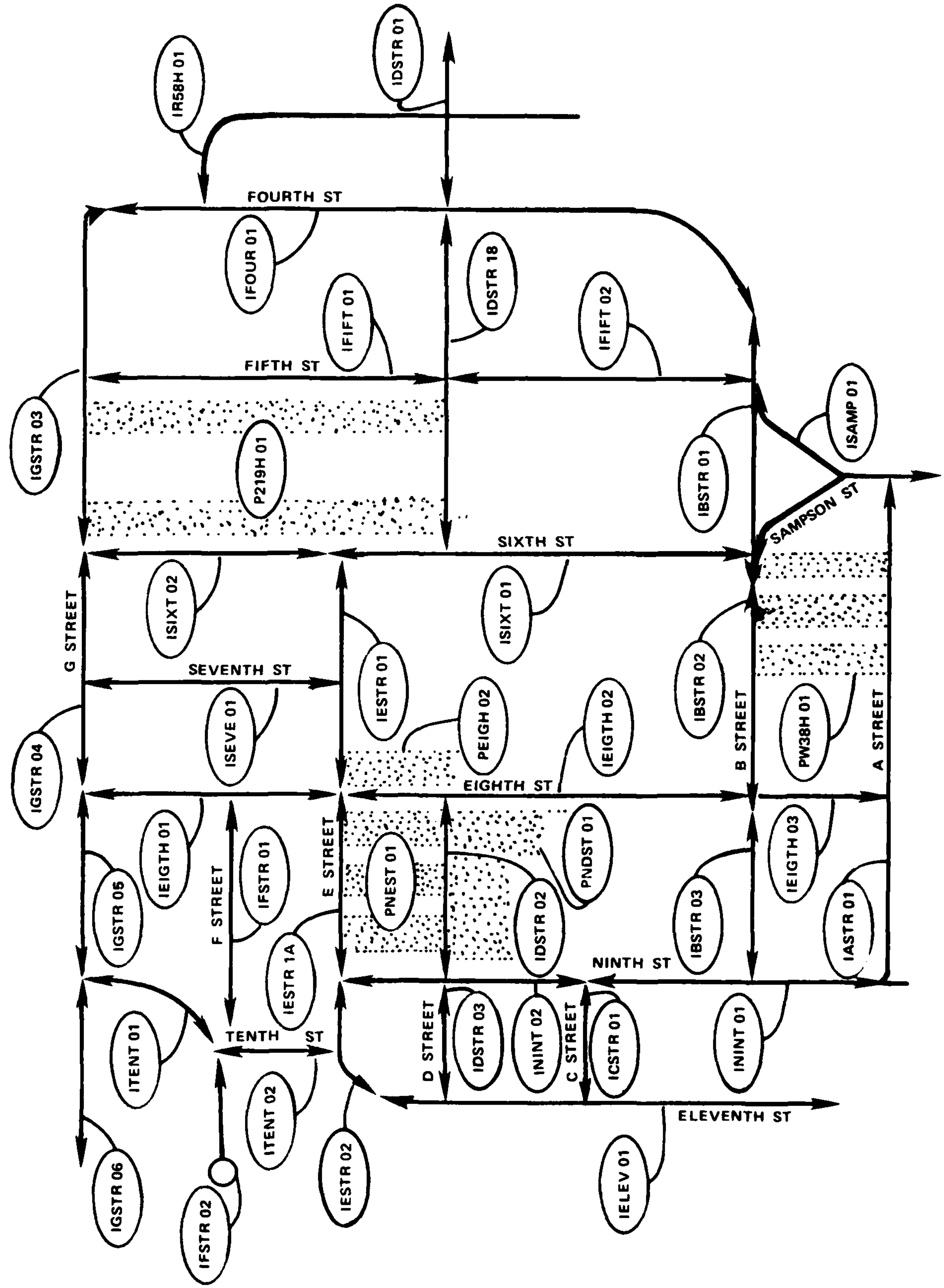

Figure 1. Sectionalized pavement network.

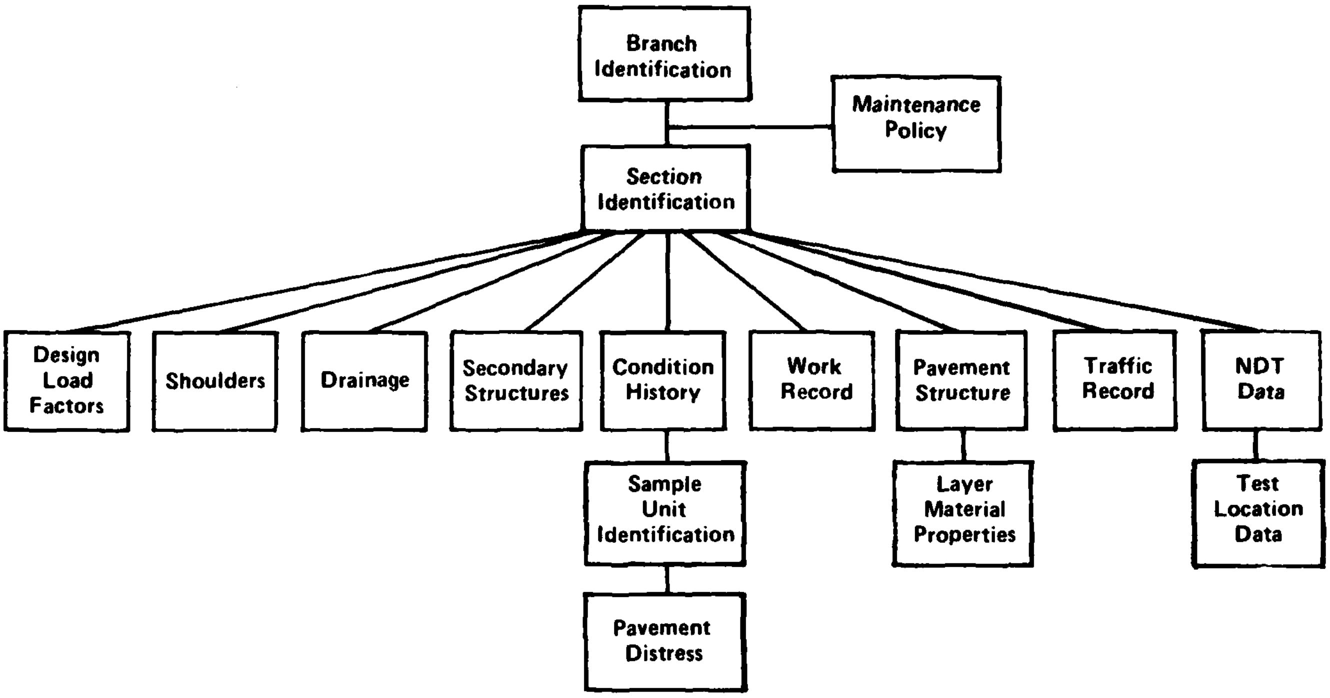

Figure 2. PAVER pavement management system database structure.

Another necessary activity is determining what data to collect. Figure 2 represents all the data elements that can be collected for the pavement network.[6] Although all this data can be collected and stored in the database, it is not necessary to have all of it. *Management needs must dictate what data is to be collected.* The minimum data elements that *must* be collected are: branch and section identification information, one pavement inspection, and pavement structure information consisting of the surface type and date of construction or last overlay. This is enough information to begin managing at the network level. Other useful information that may be collected for use in certain network-level management activities is data on traffic. This is followed in importance by coring to determine or verify layer thickness and nondestructive deflection testing (NDT) for determining structural deficiencies. Most of the other data elements will not be needed until individual pavement sections are managed at the project level. However, if certain pavement sections will be studied immediately at the project level to develop a specific repair or maintenance project, then all of the required data elements for those sections must be collected initially.

The amount of data to be collected must also be determined. This amount also depends on whether individual pavement sections are to be managed at the network or the project level initially. Network-level data can be generalized, but project-level data is more detailed (see Chapters 3 and 4). Traffic data is an example. Average daily

[6] M.Y. Shahin, *Pavement Management, the PAVER System: User's Guide*, ADP Manual 356-1 (FESA, 1985); USA-CERL Technical Manuscript M-310.

traffic (ADT) information is adequate for network-level management, but heavy truck traffic volumes are needed at the project level. In defining pavement sections, plans should be made to study all available "as built" drawings and construction records to determine the pavement structure and dates of construction. A reasonable amount of coring should also be planned to verify information gathered from the records. For managing at the network level, it will not be necessary to core every section. Instead, a representative number should be chosen and the results extrapolated to other sections, as appropriate. Coring should be planned for any section that warrants a project-level evaluation for project development. Due to the time dependency of NDT data, widespread collection at the network level is usually unnecessary. Data, if collected at all at the network level, should be limited to those sections where structural problems are suspected. Chapter 4 describes NDT at the project level. In planning for the pavement inspection, network-level management condition surveys only require inspecting a percentage of sample units. Table 1 provides recommendations on the percentage requirements based on the number of sample units per section. If the results of the pavement inspections for given sections are to be used initially at the project level, TM 5-623 and USA-CERL Technical Report M-294 provide guidelines for determining the minimum number of sample units to be inspected at the project level.

Table 1

Recommended Sampling Rates for Random Samples

No. of Sample Units in Section	No. of Units To Be Inspected
1-4	1
5-10	2
11-20	3
21-40	5
more than 40	10 percent (round up to next whole sample unit)

Two other implementation activities that should be planned for are establishing a maintenance policy and a pı ritization or optimization method for selecting pavement sections for repair. (These activities take place in step 7.)

Step 6—Determining Requirements for and Obtaining Computer Hardware and Software

Virtually any stand-alone computer terminal or microprocessor can operate PAVER, with the microcomputer being the most popular choice. The *minimum* requirements for a computer system are (1) 80-column format on the monitor, (2) one disk drive, (3) 80-column printer, (4) telephone modem, and (5) appropriate communications software. Although microcomputers are more expensive than computer terminals, they give the user the flexibility of batch-loading data and downloading PAVER reports onto floppy disks. These features will decrease the cost of using PAVER and will more than make up for the extra initial costs. These are discussed in detail in the *PAVER User's Guide*. The microprocessor can also be used for tasks other than PAVER.

SECTION IDENTIFICATION RECORD

Installation Name	Date			Branch Name	Section Area	Number Of Sample Units	Section Number
Great Lakes	5	28	82	CLARK AVE (ICLAR)	24.5 Feet Wide x 449 Feet Long / 1,17_ Square Yards	5	01

Zone		Traffic Types and Uses		General Information		
				Curb and Gutter	Sidewalks	Surface Type
( ) PWMT	( ) RTCM	● Vehicular	○ Primary	○ Left	● Left 6 ft	( ) PCC
( ) PWUT	( ) SSCM	● Real Property	● Secondary	● Right	● Right 6 ft	● AC
( ) PWUT	( ) NRMC	○ Family Housing	○ Tertiary	○ None	○ None	( ) Surface Treatment
● ADCM	( ) HSNG		○ Parking – Storage			○ Other
( ) OTHR			○ Other			

Sketch
(in sketch note any subsurface drainage structures (type, location) and secondary structures, such as manholes, water shutoffs, etc

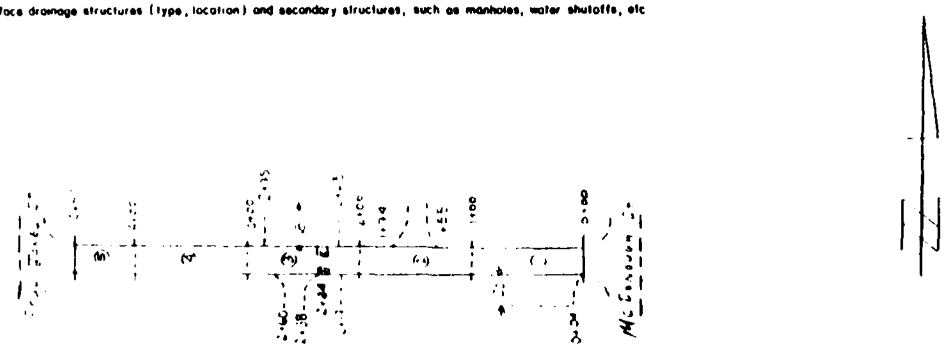

Figure 3. Pavement section identification form—typical (also note sample unit identification within section).

Step 7—Development of Preliminary System

The actual field implementation process begins in this step. Here, the detailed plan established in step 5 is carried to completion for the Phase I pavements. Several key features must be emphasized to ensure success. All sections that have been created must be field-verified to ensure that they have been defined properly. This should also be done *before* they are established into the database. Once this task is completed, section identification records should be prepared. These are very valuable records that will be used extensively when managing at both the network and project levels. Figure 3 shows an example record.

The maintenance policy established need only cover distresses found during the condition survey. The prioritization or optimization scheme developed must be reasonable and must use information easily obtained from PAVER. (Chapter 3 gives an example of a prioritization matrix and provides a detailed discussion of that topic.) Also, any data errors found must be corrected before entering into the database.

It i⁻ during this implementation period that all remaining appropriate personnel are trained regarding the use of PAVER as it relates to their specific jobs. Examples of items for which training should be provided include terminal use, data-loading procedures, standardizing inspection procedures, sampling techniques, report generation,

and report use/interpretation. Most of this training can be done "on the job" with the aid of trained in-house personnel or by a contractor. Attendance at a formal PAVER training course for additional key personnel, as decided locally, would be appropriate.

Step 8—Testing and Verifying

Once the data have been collected and loaded into the database, they must be independently verified to ensure accuracy. The PAVER manager/coordinator and the Users' Group perform this task by generating certain PAVER reports that will use the data. These include the Inventory (INV), Record (RECORD), Maintenance Policy (POLICY), and Inspection (INSPEC) reports. Any errors found must be corrected immediately. The sections themselves should be studied a final time to ensure that they have been defined properly. Items that should be carefully studied are the size of the section (too large or too small from a management perspective), pavement intersection boundaries (determining that the intersection has been placed into the correct section), and section area (for accuracy). Sample unit sizes should be checked to ensure that they fall within the guidelines as specified in Air Force Regulations 93-5, TM 5-623, and USA-CERL Technical Report M-234. Selected inspection results should be field-verified for correctness and accuracy. All errors found in the independent verification for which the contractor is responsible should be corrected by the contractor.

The database created in step 7 is established for the installation. The account may be established by either the installation or the contractor for the installation. Either way, the contractor must be held accountable for the accuracy of the data loaded. All costs to "clean up" the database must be borne by the contractor. If a contractor has loaded data on the installation account, the sign-on password must be changed after the contract is complete. Data loaded on a contractor account will be transferred to the installation when the contract is complete.

All problems that occur during Phase I implementation and any corrective action taken should be well documented. This list of "lessons learned" will be invaluable in completing implementation of the remaining phases. All personnel should become very familiar and comfortable with using PAVER. The simplest way of doing this is to have the appropriate personnel operate the system for a few hours. This will serve as a confidence builder for those who must generate reports and rely on the information obtained. Since the amount of data stored in PAVER will be small, this will not be a costly operation and will reap great benefits.

Step 9—Demonstration of the System

With the Phase I implementation complete and all errors corrected, the actual management of those sections can begin. This is a significant accomplishment and should be demonstrated to the steering committee and other interested parties. It will convince top management personnel that the effort involved in implementing PAVER is beginning to pay off and that the Users' Group is moving in the right direction with the implementation. Another key purpose in demonstrating the system at this time is to show what PAVER *can* and *cannot* do. This will help avoid the problem of overestimating PAVER's capabilities.

Step 10—Establish Location Within the Organization

PAVER must officially reside somewhere in the organization. A logical and proper choice would be with the pavement engineer who has also served as the PAVER manager/coordinator. However, if that is not desirable, or if management prefers to

split these functions, then it is at this stage of the implementation that the decision must be made. Responsibilities include database updates and monitoring the costs of using the system. It is strongly recommended that access to editing the database be very restrictive. This will safeguard the database from unauthorized editing and possible damage. Also, the bills for computer use will be received and verified. This process will serve as a check and balance on PAVER use by others and will minimize operating costs. However, this will not preclude other offices from accessing PAVER from other terminals if desired.

Step 11—Full-Scale Implementation

If all of the previous steps have been done properly, all appropriate personnel should be well versed in PAVER, and much experience will have been gained from the Phase I implementation. The detailed implementation plan for Phase I should be used for the remaining phases. In essence, steps 5, 7, and 8 will be repeated for each phase, with the lessons learned from the previous phase incorporated into planning for the next phase. This will permit implementation of the remaining phases to progress smoothly and be relatively trouble-free. All remaining pavements will be incorporated on a phase-by-phase basis. If appropriate for project-level management, more data can be collected from sections that have been implemented previously. Full-scale implementation will maximize the overall benefits of pavement management and produce a complete pavement inventory. Upon completion of the remaining phases, all of the station maps should be updated to reflect pavement sectioning. Figure 1 provides an example.

Step 12—Routine Operation

This is the routine use of PAVER and involves managing pavements at both the network and project levels (see Chapters 3 and 4). This step will begin as soon as Phase I is implemented and will progress long after all remaining phases have been implemented.

Step 13—Maintenance and Improvement of Database

The PAVER database created during the implementation process must be dynamic to be useful. The inventory must be kept current as new pavement is added and/or old pavement is removed. New personnel who must use PAVER in their jobs must be trained in the proper use of the system. Periodic refresher training may be needed for pavement inspectors, and since a pavement network is constantly deteriorating, the pavements must be reinspected periodically so that their true condition is known. Work completed and cost information should be updated annually.

Summary

The implementation of PAVER is no small undertaking, so it should be carefully planned and executed to ensure successful completion. A step-by-step implementation procedure in which the pavement sections are gradually incorporated into PAVER has been found to be the best approach. Improper implementation can lead to increased costs, a poorly defined network, an inaccurate and inappropriate database, and an

organization unwilling to use the system. To further assist the user, Appendix B provides an implementation checklist, obtained from experienced PAVER users, that outlines recommended implementation actions. Also, several publications[5] illustrate the various experiences of others.

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[5]T. D. Bruder, "Paver Implementation (...Some Potholes to Avoid)," *Navy Civil Engineer*, Vol XXV, No.1 (Spring/Summer 1985), pp 30-31; D. R. Uzarski, "PAVER Paves the Way at Great Lakes," *Navy Civil Engineer*, Vol XXIII, No. 1 (Spring 1983), pp 12-14; J. H. Roberts, "Implementation Issues of a Pavement Management System for Corps of Engineers District," *North America Pavement Management Conference Proceedings*, Vol II (1985), pp 8.74-8.82; W. Wells, M. Y. Shahin, R. E. Smith, and M. I. Darter, "Implementing Pavement Management Systems, Dos and Don'ts at the County/City Level," *North American Pavement Management Conference Proceedings*," Vol II (1985), pp 8.60-8.73.

3 MANAGING AT THE NETWORK LEVEL

Concept

Network-level management encompasses management activities associated with the total pavement network or with subnetworks of roadways, runways, etc, or zones. Management decisions are often of a general nature and are usually made with limited amounts of data.

Management Activities (Overview)

A wide variety of management tasks must be accomplished at the network level. These include selecting for inspection and doing routine condition ratings on individual pavement sections; predicting the overall condition of the network and of individual sections at some future time; evaluating pavement sections to determine the need for major repair, routine maintenance, or preventive maintenance; deciding, usually with the help of a prioritization or optimization scheme, when individual pavement sections should be maintained or repaired within budgetary constraints; developing budgets, funding scenarios, and devising strategies to maintain and repair the network to meet specified performance levels; and developing both short-term and long-range work plans.

Selecting Sections for Inspection and Inspection Scheduling

A systematic schedule must be developed that will target sections for inspection that are below an inspection minimum Pavement Condition Index (PCI), provide for a reasonable reinspection interval for all sections based on rate of deterioration and manager's choice, and be flexible enough to accommodate labor availability, current construction schedules, and unforeseen conditions.

To help schedule reinspections, the Inspection Schedule Report (SCHED) evaluates an inspection minimum PCI, a maximum reinspection interval, and the rate of deterioration to determine the year to reinspect each section.

Inspection Minimum PCI

The inspection minimum PCI is at a relatively high level as compared to the minimum acceptable PCI, which is used to flag sections for repair. This is because one of the objectives of pavement management is to identify, monitor, and repair sections early while the repairs are less expensive. This monitoring is done with the reinspections.

The inspection minimum PCI should be above the PCI at which the rate of deterioration begins to increase. The rate of deterioration usually increases at the point at which the load-related distress begins to appear. Above this PCI, most distresses are related primarily to climate and durability and have less effect on the PCI than the load-related distresses. Climate/durability distresses usually increase at a more or less constant rate, while load-related distresses increase at an accelerating rate.

Determination of the percentage of load- or climate-related distresses is provided on the Inspection Report (INSPEC) (Figure 4). To determine the inspection minimum PCI, the percent of load-related distresses for a sampling of sections for each branch

REPORT DATE- 02/25/85 PAVEMENT INSPECTION

AGENCY NUMBER = 051855 VINT HILL FARMS STATION

BRANCH NAME - PATROL ROAD	SECTION LENGTH - LF
BRANCH NUMBER - IVPAT	SECTION WIDTH - LF
SECTION NUMBER - 04	SECTION AREA - 3905 SY

INSPECTION DATE - 02/10/84 PCI= 60 RATING= GOOD
CONDITION- RIDING-2 SAFETY-2 DRAINAGE-1 SHOULDERS- OVERALL-2

TOTAL NUMBER OF SAMPLES IN SECTION=	16
NUMBER OF SAMPLES SURVEYED=	3
RECOMMENDED SAMPLES TO BE SURVEYED=	16
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED=	23.4

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
01 ALLIGATOR CR	LOW	959 SF	2.72	19.0
01 ALLIGATOR CR	MEDIUM	1599 SF	4.54	37.4
03 BLOCK CR	LOW	3976 SF	11.31	9.0
03 BLOCK CR	MEDIUM	3454 SF	9.82	15.8
06 DEPRESSION	LOW	640 SF	1.82	4.7
06 DEPRESSION	MEDIUM	959 SF	2.72	12.5
07 EDGE CR	LOW	304 LF	0.86	2.8
07 EDGE CR	MEDIUM	592 LF	1.68	10.5
10 LONG/TRANS CR	LOW	565 LF	1.60	3.8

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD RELATED DISTRESSES = 60.35 PERCENT DEDUCT VALUES.

CLIMATE/DURABILITY RELATED DISTRESSES = 24.76 PERCENT DEDUCT VALUES.

OTHER RELATED DISTRESSES = 14.89 PERCENT DEDUCT VALUES.

Figure 4. Inspection (INSPEC) report.

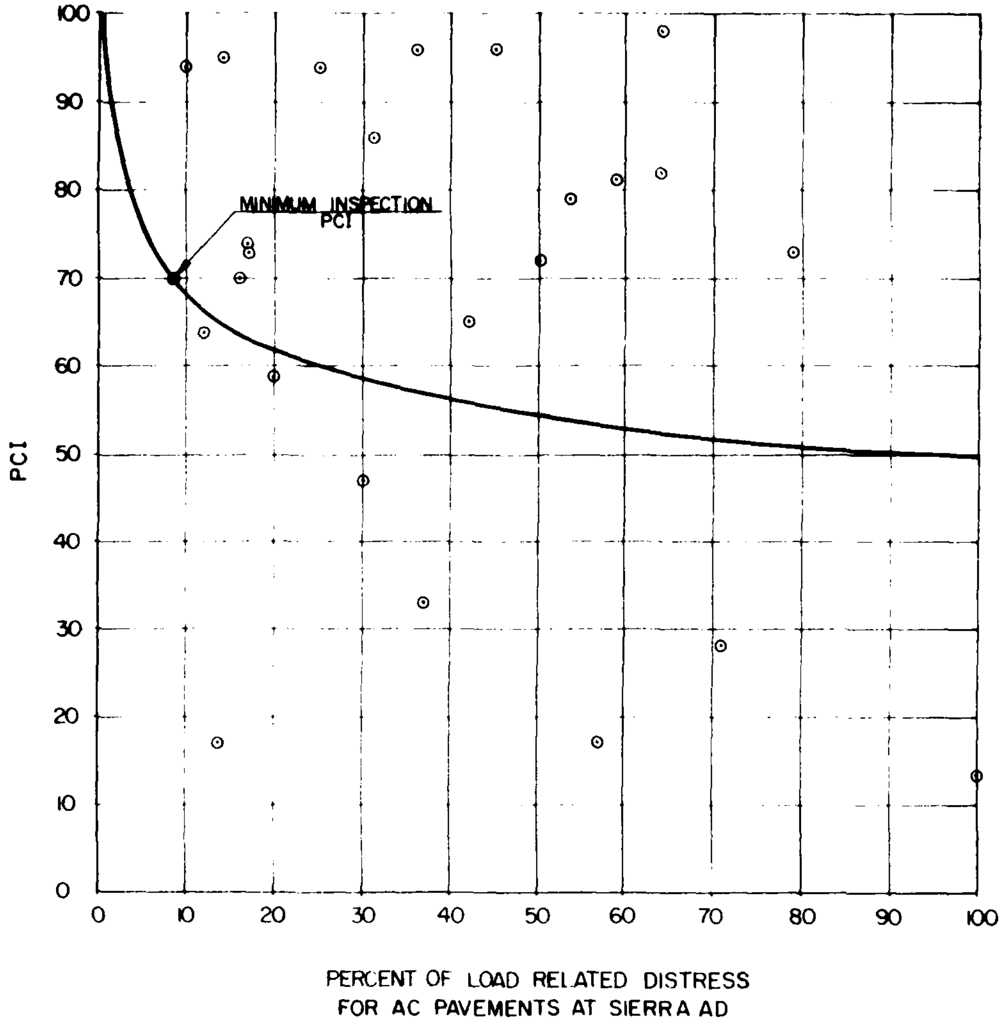

Figure 5. Example PCI versus percent load distress plot.

use, pavement rank, and surface type should be plotted against the PCIs for those sections. The PCI at which the percentage begins to increase should be a lower limit for the minimum acceptable PCI for inspection scheduling. Figure 5 provides an example plot. The curve on Figure 5 is an example and was developed using a commercially available curve-fitting program on a microprocesser. Due to the wide spread of data points (actual data from a military installation), the correlation is rather poor. For networks with less data scatter, it may be possible to simply manually curve-fit the data. This plot should be done after the implementation and prior to the first reinspection cycle. A replotting need only occur every few years or so.

The final selection of the inspection minimum PCI will require a judgment decision based on the manager's choice, current conditions, policies, PCI, and distress percentage data. It is recommended that a PCI of 80 for airfields, 70 for roads and streets, and 60

for parking lots be used as starting points until more data are available and the manager becomes familiar with the PCI and distress trends of the local network.

Maximum Reinspection Interval

The maximum reinspection interval is the maximum interval in which all sections, regardless of PCI, will be reinspected. It is recommended that this interval not exceed 3 years. This interval should be selected based on inspection data requirements, manpower availability, and inspection budget level. A shorter interval will provide better inspection data and more reliable PCI projections.

Rate of Deterioration

A section with a high rate of deterioration should be inspected more often to determine if the deterioration is continuing at the same rate or changing. A reinspection should also be performed to evaluate the type and extent of distress that caused the deterioration. These sections will require repairs in a short period of time because the pavement is not performing as intended. Table 2 provides recommended reinspection intervals based on the rate of deterioration.

Table 2

Recommended Intervals Based on Rate of Deterioration

Rate of Deterioration PCI/Year	Reinspection Interval (Year)
>10	1
6 to 10	2
2 to 5	3
<2	3

Computer-Generated Inspection Schedules

PAVER provides a report that gives a multi-year inspection schedule for the entire network or for specific subnetworks (Zones). This SCHED report selects sections for reinspections based on the branch use, pavement rank, surface type, zone, and section category coupled to the inspection minimum PCI, maximum reinspection interval, and deterioration rate.

The program evaluates each section against the established inspection interval criteria, then selects the earliest year to reinspect. Once the year to inspect is selected, the program groups the sections by year to reinspect and orders the groups by branch and section number. The report can print a table, histogram, and section listing by year. Figure 6 provides a sample SCHED report. This report should be run annually prior to the inspection season.

```
                    INSPECTION SCHEDULE REPORT
AGENCY NAME: FT. MCNAIR                  REPORT DATE:  85/08/25.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC
ZONE        : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N
                      INSPECTION SCHEDULE TABLE
```

FY TO INSP.	NO. OF SECT. TO INSP.	PAVEMENT RANK PRIMARY	SECONDARY	TERTIARY	OTHER	NOT APPLIC
1985	11	11	0	0	0	0
1986	1	1	0	0	0	0
1987	0	0	0	0	0	0
1988	22	22	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0

```
   TOTAL NO. OF SECTION:       34
   SECT. NOT NEEDING INSPECTION:      0
   NO. OF MISSING VALUE:        0
```

```
                    INSPECTION SCHEDULE REPORT
AGENCY NAME: FT. MCNAIR                  REPORT DATE:  85/08/25.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC
ZONE        : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N


 NO.  FY TO
 SEC. INSP.
              !
              !
  11  1985    !***************************
              !
              !
   1  1986    !**
              !
              !
   0  1987    !
              !
              !
  22  1988    !******************************************************
              !
              !
   0  1989    !
              !
              !
   0  1990    !
              !
              !
 ----         !--------------!--------------!--------------!--------------!
  34          0              6             12             18             24

                         NO OF SECTIONS


  TOTAL NO. OF SECTION:       34
  SECT. NOT NEEDING INSPECTION:      0
  NO. OF MISSING VALUE:        0
```

Figure 6. Inspection Scheduling (SCHED) report.

INSPECTION SCHEDULE REPORT

AGENCY NAME: FT. MCNAIR REPORT DATE: 85/08/25.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC
ZONE : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N

LIST OF CASES IN
INSPECTION SCHEDULE REPORT

FY TO INSPECT : 1985 NO. OF SECTIONS : 11

BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC AREA	FROM	TO
I3AVE	ROADWAY	02	P	AC	952	N SIDE BLDG 20	S SIDE BLDG 21
I3AVE	ROADWAY	03	P	AC	252	E CURB I3AVE02	E CURB I3AVE02
I4AVE	ROADWAY	02	P	AC	6471	S WALL AT RIVER	S CURB B ST
I4AVE	ROADWAY	03	P	AC	125	WAR COLLEGE	W CURB I4AVE02
I5AVE	ROADWAY	02	P	AC	400	S CURB B ST	200' S S CURB B
I5AVE	ROADWAY	06	P	AC	600	200' S OF B ST	500' S OF B ST
I5AVE	ROADWAY	08	P	AC	1786	N SIDE POOL LOT	N CURB AT GATE 2 ST
IBSTR	ROADWAY	01	P	AC	406	W WALL	W CURB 2 AVE
IBSTR	ROADWAY	03	P	AC	160	N CURB B ST 02	N CURB B ST 02
ICSTR	ROADWAY	03	P	AC	706	E CURB 3RD AVE	W CURB 5TH ST
IESTR	ROADWAY	02	P	AC	553	N EDGE E ST CIRCLE	S WALL WAR COLLEGE

FY TO INSPECT : 1986 NO. OF SECTIONS : 1

BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC AREA	FROM	TO
IBSTR	ROADWAY	04	P	AC	656	45' E E CURB 3AVE	E CURB 4AVE

FY TO INSPECT : 1988 NO. OF SECTIONS : 22

BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	SEC AREA	FROM	TO
I1AVE	ROADWAY	01	P	AC	431	N CURB A ST	N WALL
I1AVE	ROADWAY	02	P	AC	711	S CURB A ST	N CURB B ST
I1AVE	ROADWAY	03	P	AC	6933	S CURB B ST	W CURB 2 AVE
I2AVE	ROADWAY	01	P	AC	5627	S CURB B ST	S CURB WAR COLL LOT
I2AVE	ROADWAY	02	P	AC	1029	S CURB WAR COLL LOT	S CURB
I3AVE	ROADWAY	01	P	AC	1791	S CURB M ST	N CURB B ST
I4AVE	ROADWAY	01	P	AC	1350	N CURB B ST	N SIDE BLDG 31
I5AVE	ROADWAY	01	P	AC	774	LAMP POST B & 5	268' N END CURB E
I5AVE	ROADWAY	03	P	AC	1222	N CURB GATE 2 ST	E CURB 4TH AVE
I5AVE	ROADWAY	04	P	AC	740	W CURB 5 AVE	W CURB 5 AVE
I5AVE	ROADWAY	05	P	AC	394	E CURB 4 AVE	W CURB 5 AVE
I5AVE	ROADWAY	07	P	AC	1140	500' S OF B ST	N SIDE POOL LOT
IACCE	ROADWAY	01	P	AC	330	N SIDE BLD 48 ANNEX	10' S BLDG 50
IASTR	ROADWAY	01	P	AC	728	15' E W BLDG 48	W CURB 1 AVE
IASTR	ROADWAY	02	P	AC	740	W CURB 3 AVE	100'S N SIDE BLD 48
IASTR	ROADWAY	03	P	AC	818	15' E OF BLDG 31	E CURB 3RD AVE
IBSTR	ROADWAY	02	P	AC	922	W CURB 2 AVE	45'E E CURB 3 AVE
IBSTR	ROADWAY	05	P	AC	800	E CURB 4AVE	CURB E END
ICSTR	ROADWAY	01	P	AC	347	E CURB 1AVE	W CURB 2AVE
ICSTR	ROADWAY	02	P	AC	1600	E CURB 2AVE	W CURB 3AVE
IDSTR	ROADWAY	01	P	AC	1200	W CURB 4AVE	E CURB 2AVE
IESTR	ROADWAY	01	P	AC	1974	14' E E CURB 2AVE	W CURB 4AVE

TOTAL NO. OF SECTION: 34
SECT. NOT NEEDING INSPECTION: 0
NO. OF MISSING VALUE: 0

MINIMUM PCI TABLE

	P	S	T	X	N
ROADWAY	70	70	70	70	70

RATE(PTS/YR)	RATE LIMIT YRS TO INSP
GT 10	1
6 - 10	2
2 - 5	3
LT 2	3

Figure 6 (Cont'd).

Manpower Availability

One of the most important factors in scheduling inspections is having enough trained manpower available to perform the inspections. If full-time personnel will be used, inspections should be scheduled to be done with other annual inspection functions. If full-time personnel are not available, reliable inspections can be obtained by training part-time or temporary personnel such as college students, or by having another agency or a contractor perform the inspections. Inspections can be scheduled when this part-time help is available, such as during the summer. Contracting with trained consultants can be advantageous, because although they tend to have higher wages, they may also be more productive. Consultants can also be scheduled for any time of the year.

It may be desirable from a personnel management perspective to balance inspections from year to year; sections identified as needing inspection one fiscal year can be moved to another year to balance manhours. For example, if after analyzing the SCHED report it is estimated that 500 hours will be required one year and 50 hours the next year, it would be acceptable to do approximately 275 hours of inspecting each year to balance the inspection time.

Construction Schedule

Sections that appear on the inspection list that have major repairs scheduled need not receive an additional network-level inspection; however, a project-level inspection *must* be performed (see Chapter 4).

Sections that have received major repairs should be inspected the year after the repairs are done. This will allow data to be collected about the effectiveness of the repair and establish initial deterioration rates. However, those sections will *not* appear in the SCHED report because they will not meet the previously established inspection scheduling criteria; therefore, they must be scheduled manually. After this one inspection is completed, more inspections can be scheduled using the SCHED report.

Unusual Phenomena

Inspections should also be scheduled manually for sections that experience some type of catastrophic event, such as a flood or rapid spring thaw. Any event that causes an extreme drop in PCI should be an inspection factor.

Performing Network-Level Inspections

Sampling Rate

Network-level inspections must be performed on a representative basis. Sample units should be selected systematically. Table 1 provides a recommended inspection rate for random samples.

The recommended inspection rate should be used for initial implementation and for periodic reinspections. Depending on the overall size of the sections in the road network, this rate will provide about a 20 to 25 percent overall sampling rate; however, it will not be acceptable for project-level work. For the project level, choosing a sampling rate will depend on the level of accuracy the installation feels is adequate and the purposes for which these inspections will be used. In reality, PCIs will vary even slightly among sample units. Using these very low sampling rates will result in error because this

assumes that mean PCI of inspected sample units are statistically no different from the true PCI of the section. The INSPEC, or Current Inspection (INSPCUR), report provides sampling rates which, if applied, will produce a more accurate section PCI. (Project-level inspections will be discussed in Chapter 4.) For network-level management, such a high degree of accuracy on the PCI and extrapolated distress quantities is not needed. Even with these reduced sampling rates, the PCI will be representative of the section. Therefore, the extra inspection time required for the higher sampling rates is not warranted at the network level.

One factor that must be considered with random sampling is the occurrence of nontypical distresses, such as railroad crossings, and poor or excellent sample units that differ significantly from the typical sample unit within a section. These sample units should be identified as additional sample units and inspected in addition to the random sample units.

Unlike the distresses from the random sample units, which are extrapolated over the section, the distresses from an additional sample unit are not extrapolated. The extrapolation and the PCI calculation for random sample units are performed over the section area minus the area of the additional sample units. The distresses from the additional sample units are then added to the random extrapolated quantities. This prevents extrapolating a distress such as railroad crossings over the entire section. It also provides a more accurate representation of the section PCI. TM 5-623 and USA-CERL Technical Report M-294 provide a detailed discussion of this topic.

Initial Inspections

For initial inspections, the selection of sample units should be done so that the required number of sample units is inspected and so that these sample units represent the entire section. For roads, runways, and taxiways with many sample units, a systematic random sampling procedure should be used; for short sections, purely random procedures may be used. These are described in Air Force Regulation 93-5, TM 5-623, and USA-CERL Technical Report M-294. These procedures also apply to aprons and parking lots, but for simplicity, selected sample units may have to be spaced fairly evenly over the section. These sample units need not be in a specific numerical order.

Regardless of how the sample units are selected, they must represent the entire section. If a chosen sample unit is not representative, it should be inspected as an additional sample unit and another random sample unit chosen in its place. Random sample units should be selected in the office to avoid any bias that may occur if sample units are studied in the field before inspection.

Reinspecting Sample Units

When reinspecting at the network level, using low sampling rates, it is advisable to reinspect the same sample units inspected before, including both random and additional sample units. It is very important to know the deterioration rates of the various pavement sections; thus, inspecting the same sample units each time will show the true change in each sample unit. This will then be reflected as the change for the entire section. If different sample units are inspected, a small change in PCI can be attributed to the different sample units inspected, and this could lead to a serious error in the PCI projection for the sections.

The error attributable to using reduced sampling rates in determining the section PCI can easily be tolerated at the network level because the overall effects on the

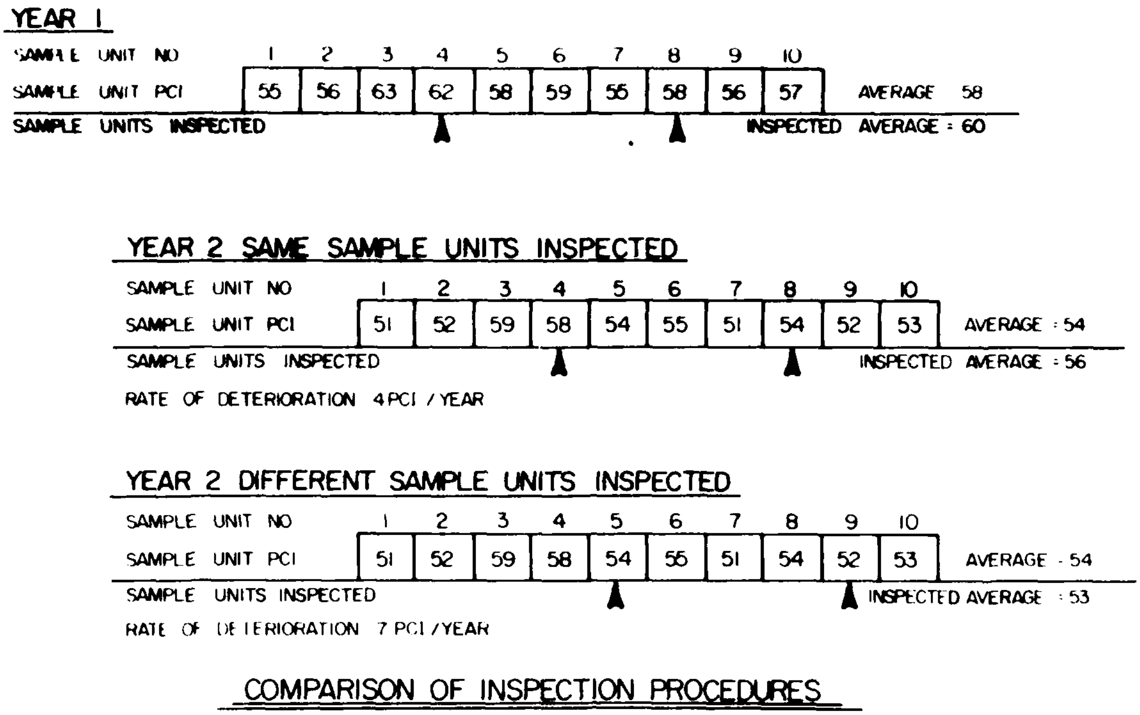

Figure 7. Example pavement section with sample unit PCIs.

decision making are small; however, it is extremely important that the deterioration rates of the sections be represented accurately. Even small errors in determining the deterioration rate can lead to misleading representations of future PCIs. This error is essentially eliminated if the same sample units are inspected each time. This is best illustrated by the following example.

Figure 7 represents a pavement section with 10 sample units, of which two were initially selected for inspection. For this example, assume that the PCIs for each sample unit are as shown in the figure and that sample units 4 and 8 were inspected, giving an average PCI of 60. If all the sample units had been inspected and the PCIs calculated, the section PCI would have been 58. As previously discussed, this is a small error and can be tolerated easily. If each sample unit were deteriorating about four points per year, by sampling the same sample units (4 and 8) the following year, this four-point PCI deterioration would be represented accurately, and the section PCI should be 56. However, if the same sample units were not inspected the following year and, say, sample units 5 and 9 were inspected instead, their average PCI would be 53. From the results of these two inspections, it would be incorrectly concluded that the section had deteriorated by seven points, rather than four points. Although this amount is still small, when the results are projected to a program year for project planning, a fairly large difference in PCI would result. Later inspections would most likely rectify this error; however, these constant changes will lead to inconsistent decision making at the network level. This can all be avoided if the same sample units are inspected each time.

Naturally, situations will occur when this policy should not be followed. The most likely possibility would be unique changes to certain sample units within a section. The inspector should always be aware of those situations and use of additional sample units, where warranted.

The Current Sample Unit Inspection Report (SAMPCUR) should be run to find which sample units were inspected previously. This report will provide inspection data on each sample unit and the extrapolated distress data.

Sections with PCIs below about 20 need only receive cursory reinspections if maintenance or repairs have not been performed since the last inspection. This can save considerable inspection time. The reason that cursory inspection will suffice is that network-level management decisions are usually unchanged once the PCI drops below about 20.

Documenting Conditions

The field inspection team documents the field data. The most important aspect of identifying and recording distress data is consistency.

A two-person inspection team will provide good results. It will allow the field inspectors to discuss questionable distresses and also to rotate tasks such as measuring and recording distress data, which will help break the monotony and maintain some level of enthusiasm.

Periodic inspection checks will also help maintain inspection consistency. This can be done by periodically reinspecting certain sample units to see if the same distresses and severities are identified. Some deviation between these inspection checks can be expected and is acceptable, but the supervisor should flag large differences in the PCI. (A difference of more than 3 should be checked carefully.) To help ensure consistency, inspectors should take the distress manuals into the field. Relying on memory to identify and measure distress type and severity level will give inconsistent results. A competent team should be able to inspect a sample with a mid-range PCI in 10 to 15 minutes, including travel time to the next sample unit.

Field data sheets should be easy to complete and easy to read. This will greatly facilitate transfer of data from the field sheets to the computer data input. Many data input errors can be prevented by using easily read field data sheets. Figure 8 provides an example. TM 5-623 and USA-CERL Technical Report M-294 illustrate other examples.

Advancements in portable computer hardware now make it possible to take a portable computer into the field so that field inspection data can be loaded directly onto cassettes, floppy disks, or the computer memory itself. This type of hardware is relatively inexpensive. For installations that must perform inspections annually, this type of hardware will be cost-effective because it eliminates the need for clerical personnel to transfer data from field sheets to the PAVER database, since the portable computer can be used to communicate directly to the mainframe computer. Software for several types of microcomputers is currently available within PAVER (see *PAVER, User's Guide*), and others are available commercially. Using these computers also reduces errors from manually transposing data.

Data review will involve determining new conditions and comparing them to those found in previous inspections. Current conditions can be determined with the INSPCUR or SAMPCUR reports. INSPCUR will generate the section PCI, the extrapolated distress

INSPECTION IDENTIFICATION FORM
ASPHALT SURFACES

*FORM ID	*INSPECTION DATE (MMDDYY)	*BRANCH NUMBER	*SECTION NUMBER	*A/C/D
017	011685	IVPAT	04	A

RIDING	SAFETY	DRAINAGE	SHOULDERS	OVERALL	TOTAL NUMBER OF SAMPLE UNITS
1	2	1	1	1	9

INSPECTION RESULTS

*FORM ID	SAMPLE UNIT NUMBER	SAMPLE TYPE	AREA OF SAMPLE
018	3	R	2200

DISTRESS CODE	SEVERITY	TOTAL QUANTITY	DISTRESS CODE	SEVERITY	TOTAL QUANTITY
07	L	30	10	L	92

*FORM ID	SAMPLE UNIT NUMBER	SAMPLE TYPE	AREA OF SAMPLE
018	7	R	2200

DISTRESS CODE	SEVERITY	TOTAL QUANTITY	DISTRESS CODE	SEVERITY	TOTAL QUANTITY
01	M	46	07	L	65
07	M	115	10	L	70
10	M	45			

COMMENTS (MAX 40 CHAR)

THE DRAINAGE ON THE RIGHT IS VERY POOR

Figure 8. Example field data collection sheet.

quantities, and distress analysis information. SAMPCUR will provide the same information as the INSPCUR report plus give sample unit distress and PCI information. Comparing this information with the INSPCUR or SAMPCUR reports generated *before* the inspections will allow changes in each section to be determined and evaluated. Sections that show a large change in PCI, distress quantity, or distress severity should be analyzed in more depth to determine the cause and effect of the changes. A good comparison would be to see if any distresses were eliminated or reduced when no work was done on the section. This provides a positive check on inspection errors.

If hazardous conditions are found in the field, they should be noted on the "comments" portion of the inspection sheet. These conditions, which include extremely bad ride quality, portions of missing pavement, or a large dropoff at the edge of the pavement, should be brought to the supervisor's attention. This will help prevent these conditions from being overlooked. Any type of hazardous conditions should be identified for repair immediately.

The use of the comments portion of the inspection sheet cannot be overemphasized. Comments should document any condition not covered by the given distress types. Comments on drainage, curb and gutter conditions, adjacent sidewalks, etc., are appropriate (see Figure 9).

Prediction of Network Conditions

One of the most important parts of managing any network is predicting future conditions. These predictions will play a major role in selecting sections for repair, deciding priorities, and formulating repair strategies. PAVER uses a prediction model that assumes a PCI of 100 at the date of last overlay or construction; then, based on subsequent inspections, the model determines a deterioration rate from the last inspection point, as shown in Figure 10. The prediction procedure and Figure 10 are detailed in USA-CERL Technical Manuscript M-310.

Present-Year Conditions

Present conditions can be determined from the PCI and Pavement Condition Index--Alphabetical (PCIA) reports. These reports provide some necessary information about the section, such as pavement rank, surface type, section area, and the PCI at the time of the *last inspection*. The PCI report arranges the sections in order of increasing PCI. The PCIA report arranges the section alphabetically by branch name. These reports are very useful for easily determining section PCIs and for ranking the sections according to PCI. Figures 11 and 12 illustrate these two reports.

Present conditions can also be determined from the Frequency (FREQ) report. This report will rank all sections, from lowest to highest, based on the projected PCIs. The "current PCI" given in the report is the PCI from the last inspection. The PCIs for all sections are projected to a desired "predicted date" which is input by the user. It normalizes all section PCIs to the same date. This is an advantage over the PCI and PCIA reports: FREQ will display PCIs from many dates, possibly years apart. To use the FREQ report to reflect present conditions, the user must ask for the current date as the "predicted date." Figure 13 displays a FREQ report for the present year.

```
REPORT DATE-  03/28/85            PAVEMENT INSPECTION

AGENCY NUMBER =        051855      VINT HILL FARMS STATION

------------------------------------------------------------------------------
BRANCH NAME -    PATROL ROAD                         SECTION LENGTH -       LF
BRANCH NUMBER -  IVPAT                               SECTION WIDTH -      LF
SECTION NUMBER - 04                                  SECTION AREA -     3905 SY
------------------------------------------------------------------------------
INSPECTION DATE - 03/15/85      PCI=  60     RATING=  GOOD
CONDITION- RIDING-2   SAFETY-3   DRAINAGE-2   SHOULDERS-    OVERALL-2

TOTAL NUMBER OF SAMPLES IN SECTION=                                  16
NUMBER OF SAMPLES SURVEYED=                                           3
RECOMMENDED SAMPLES TO BE SURVEYED=                                  14
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED=           12.2

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-

   DISTRESS TYPE         SEVERITY   QUANTITY     DENSITY-PCT      DEDUCT-VALUE

 01 ALLIGATOR CR         HIGH        155 SF          0.44              20.4
 01 ALLIGATOR CR         LOW          16 SF          0.04               4.0
 01 ALLIGATOR CR         MEDIUM      688 SF          1.95              27.7

 07 EDGE CR              LOW          53 LF          0.15               0.8
 07 EDGE CR              MEDIUM       53 LF          0.15               4.2

 10 LONG/TRANS CR        LOW        1391 LF          3.95               8.9
 10 LONG/TRANS CR        MEDIUM      128 LF          0.36               2.8

 11 PATCH/UTIL CUT       LOW        2836 SF          8.06              14.0

 19 WEATHER/RAVEL        LOW         171 SF          0.48               1.1

COMMENTS-
THE PAVEMENT SURFACE IS 2 IN. ABOVE THE GUTTER AND SHOULD BE TRIMMED DOWN FLUSH


     *** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

  LOAD                RELATED DISTRESSES =  68.06 PERCENT DEDUCT VALUES.

  CLIMATE/DURABILITY  RELATED DISTRESSES =  15.26 PERCENT DEDUCT VALUES.

  OTHER               RELATED DISTRESSES =  16.69 PERCENT DEDUCT VALUES.
```

Figure 9. Example use of comments on inspection sheet.

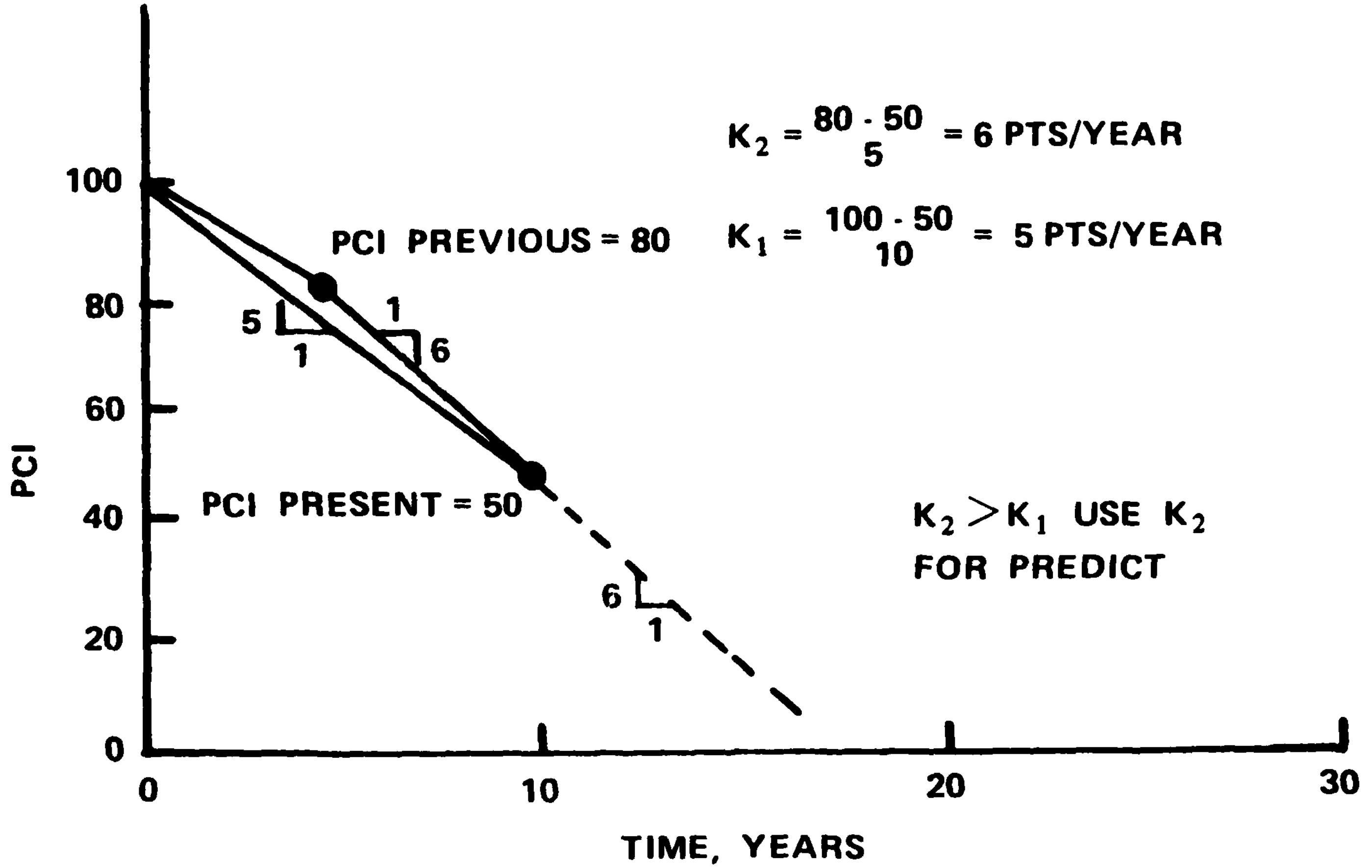

Figure 10. Example case of PCI prediction when PCI was previously determined.

REPORT DATE- 02/27/85 PCI REPORT

AGENCY NUMBER = 011605 FT. MCNAIR

BRANCH NUMBER/NAME	SECTION NUMBER	PAV. RANK	SURF. TYPE	SECTION AREA/SY	INSPECTION DATE	PCI
I3AVE*THIRD AVE	02	TERTIARY	AC	952	11/13/83	16
BRANCH USE- ROADWAY [FROM]- N SIDE BLDG 20				[TO]-S SIDE BLDG 21		
I3AVE*THIRD AVE	03	TERTIARY	AC	252	11/13/83	19
BRANCH USE- ROADWAY [FROM]- E CURB I3AVE02				[TO]-E CURB I3AVE02		
ICSTR*C ST	03	SECONDARY	AC	706	11/13/83	32
BRANCH USE- ROADWAY [FROM]- E CURB 3RD AVE				[TO]-W CURB 5TH ST		
I5AVE*FIFTH AVE	08	SECONDARY	AC	1786	11/12/83	33
BRANCH USE- ROADWAY [FROM]- N SIDE POOL LOT				[TO]-N CURB AT GATE 2 ST		
IBSTR*B ST	01	SECONDARY	AC	406	11/13/83	48
BRANCH USE- ROADWAY [FROM]- W WALL				[TO]-W CURB 2 AVE		
IBSTR*B ST	03	TERTIARY	AC	160	11/13/83	52
BRANCH USE- ROADWAY [FROM]- N CURB B ST 02				[TO]-N CURB B ST 02		
I4AVE*FOURTH AVE	03	TERTIARY	AC	125	11/13/83	52
BRANCH USE- ROADWAY [FROM]- WAR COLLEGE				[TO]-W CURB I4AVE02		
I4AVE*FOURTH AVE	02	PRIMARY	AC	6471	11/13/83	66
BRANCH USE- ROADWAY [FROM]- S WALL AT RIVER				[TO]-S CURB B ST		
I5AVE*FIFTH AVE	06	SECONDARY	AC	600	11/12/83	67
BRANCH USE- ROADWAY [FROM]- 200' S OF B ST				[TO]-500' S OF B ST		
I5AVE*FIFTH AVE	05	TERTIARY	AC	394	11/12/83	78
BRANCH USE- ROADWAY [FROM]- E CURB 4 AVE				[TO]-W CURB 5 AVE		

Figure 11. Pavement condition index (PCI) report.

```
------------------------------------------------------------------------------
IBSTR*B ST                    04     PRIMARY   AC      656    11/15/83    81
 BRANCH USE-  ROADWAY   [FROM]- 45' E E CURB 3AVE      [TO]-E CURB 4AVE
------------------------------------------------------------------------------
I5AVE*FIFTH AVE               03     SECONDARY AC     1222    11/12/83    84
 BRANCH USE-  ROADWAY   [FROM]- N CURB GATE 2 ST       [TO]-E CURB 4TH AVE
------------------------------------------------------------------------------
I5AVE*FIFTH AVE               07     SECONDARY AC     1140    11/12/83    87
 BRANCH USE-  ROADWAY   [FROM]- 500' S OF B ST         [TO]-N SIDE POOL LOT
------------------------------------------------------------------------------
I5AVE*FIFTH AVE               02     SECONDARY AC      400    11/12/83    91
 BRANCH USE-  ROADWAY   [FROM]- S CURB B ST            [TO]-200' S S CURB B
------------------------------------------------------------------------------
IESTR*E ST                    02     TERTIARY  AC      553    11/13/83    93
 BRANCH USE-  ROADWAY   [FROM]- N EDGE E ST CIRCLE     [TO]-S WALL WAR COLLEGE
------------------------------------------------------------------------------
I3AVE*THIRD AVE               01     PRIMARY   AC     1791    11/13/83    97
 BRANCH USE-  ROADWAY   [FROM]- S CURB M ST            [TO]-N CURB B ST
------------------------------------------------------------------------------
ICSTR*C ST                    02     SECONDARY AC     1600    11/13/83    99
 BRANCH USE-  ROADWAY   [FROM]- E CURB 2AVE            [TO]-W CURB 3AVE
------------------------------------------------------------------------------
IACCE*ACCESS RD               01     TERTIARY  AC      330    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- N SIDE BLD 48 ANNEX    [TO]-10' S BLDG 50
------------------------------------------------------------------------------
IASTR*A ST                    01     SECONDARY AC      728    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- 15' E W BLDG 48        [TO]-W CURB 1 AVE
------------------------------------------------------------------------------
IASTR*A ST                    02     SECONDARY AC      740    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- W CURB 3 AVE           [TO]-100'S N SIDE BLD 48
------------------------------------------------------------------------------
IASTR*A ST                    03     SECONDARY AC      818    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- 15' E OF BLDG 31       [TO]-E CURB 3RD AVE
------------------------------------------------------------------------------
IBSTR*B ST                    02     PRIMARY   AC      922    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- W CURB 2 AVE           [TO]-45'E E CURB 3 AVE
```

Figure 11 (Cont'd).

```
--------------------------------------------------------------------------------
IBSTR*B ST                          05     SECONDARY AC      800    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- E CURB 4AVE              [TO]-CURB E END
--------------------------------------------------------------------------------
ICSTR*C ST                          01     SECONDARY AC      347    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- E CURB 1AVE              [TO]-W CURB 2AVE
--------------------------------------------------------------------------------
IDSTR*D ST                          01     PRIMARY   AC     1200    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- W CURB 4AVE              [TO]-E CURB 2AVE
--------------------------------------------------------------------------------
IESTR*E ST                          01     SECONDARY AC     1974    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- 14' E E CURB 2AVE        [TO]-W CURB 4AVE
--------------------------------------------------------------------------------
I1AVE*FIRST AVE                     01     TERTIARY  AC      431    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- N CURB A ST              [TO]-N WALL
--------------------------------------------------------------------------------
I1AVE*FIRST AVE                     02     SECONDARY AC      711    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- S CURB A ST              [TO]-N CURB B ST
--------------------------------------------------------------------------------
I1AVE*FIRST AVE                     03     SECONDARY AC     6933    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- S CURB B ST              [TO]-W CURB 2 AVE
--------------------------------------------------------------------------------
I2AVE*SECOND AVE                    01     PRIMARY   AC     5627    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- S CURB B ST              [TO]-S CURB WAR COLL LOT
--------------------------------------------------------------------------------
I2AVE*SECOND AVE                    02     SECONDARY AC     1029    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- S CURB WAR COLL LOT      [TO]-S CURB
--------------------------------------------------------------------------------
I4AVE*FOURTH AVE                    01     SECONDARY AC     1350    11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- N CURB B ST              [TO]-N SIDE BLDG 31
--------------------------------------------------------------------------------
I5AVE*FIFTH AVE                     01     SECONDARY AC      774    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- LAMP POST B & 5          [TO]-268' N END CURB E
--------------------------------------------------------------------------------
I5AVE*FIFTH AVE                     04     TERTIARY  AC      740    11/18/83   100
 BRANCH USE-  ROADWAY   [FROM]- W CURB 5 AVE             [TO]-W CURB 5 AVE
```

Figure 11 (Cont'd).

REPORT DATE- 02/27/85 PCI-A REPORT

AGENCY NUMBER = 011605 FT. MCNAIR

BRANCH NUMBER/NAME	SECTION NUMBER	PAV. RANK	SURF. TYPE	SECTION AREA/SY	INSPECTION DATE	PCI
IACCE*ACCESS RD	01	TERTIARY	AC	330	11/12/83	100
BRANCH USE- ROADWAY	[FROM]- N SIDE BLD 48 ANNEX			[TO]-10' S BLDG 50		
IASTR*A ST	01	SECONDARY	AC	728	11/12/83	100
BRANCH USE- ROADWAY	[FROM]- 15' E W BLDG 48			[TO]-W CURB 1 AVE		
IASTR*A ST	02	SECONDARY	AC	740	11/12/83	100
BRANCH USE- ROADWAY	[FROM]- W CURB 3 AVE			[TO]-100'S N SIDE BLD 48		
IASTR*A ST	03	SECONDARY	AC	818	11/12/83	100
BRANCH USE- ROADWAY	[FROM]- 15' E OF BLDG 31			[TO]-E CURB 3RD AVE		
IBSTR*B ST	01	SECONDARY	AC	406	11/13/83	48
BRANCH USE- ROADWAY	[FROM]- W WALL			[TO]-W CURB 2 AVE		
IBSTR*B ST	02	PRIMARY	AC	922	11/13/83	100
BRANCH USE- ROADWAY	[FROM]- W CURB 2 AVE			[TO]-45'E E CURB 3 AVE		
IBSTR*B ST	03	TERTIARY	AC	160	11/13/83	52
BRANCH USE- ROADWAY	[FROM]- N CURB B ST 02			[TO]-N CURB B ST 02		
IBSTR*B ST	04	PRIMARY	AC	656	11/15/83	81
BRANCH USE- ROADWAY	[FROM]- 45' E E CURB 3AVE			[TO]-E CURB 4AVE		
IBSTR*B ST	05	SECONDARY	AC	800	11/13/83	100
BRANCH USE- ROADWAY	[FROM]- E CURB 4AVE			[TO]-CURB E END		
ICSTR*C ST	01	SECONDARY	AC	347	11/13/83	100
BRANCH USE- ROADWAY	[FROM]- E CURB 1AVE			[TO]-W CURB 2AVE		

Figure 12. Pavement condition index—alphabetical (PCIA) report.

```
------------------------------------------------------------------------------
ICSTR*C ST                            02      SECONDARY AC     1600    11/13/83     99
 BRANCH USE-   ROADWAY    [FROM]- E CURB 2AVE               [TO]-W CURB 3AVE
------------------------------------------------------------------------------
ICSTR*C ST                            03      SECONDARY AC      706    11/13/83     32
 BRANCH USE-   ROADWAY    [FROM]- E CURB 3RD AVE            [TO]-W CURB 5TH ST
------------------------------------------------------------------------------
IDSTR*D ST                            01      PRIMARY   AC     1200    11/13/83    100
 BRANCH USE-   ROADWAY    [FROM]- W CURB 4AVE               [TO]-E CURB 2AVE
------------------------------------------------------------------------------
IESTR*E ST                            01      SECONDARY AC     1974    11/13/83    100
 BRANCH USE-   ROADWAY    [FROM]- 14' E E CURB 2AVE         [TO]-W CURB 4AVE
------------------------------------------------------------------------------
IESTR*E ST                            02      TERTIARY  AC      553    11/13/83     93
 BRANCH USE-   ROADWAY    [FROM]- N EDGE E ST CIRCLE        [TO]-S WALL WAR COLLEGE
------------------------------------------------------------------------------
I1AVE*FIRST AVE                       01      TERTIARY  AC      431    11/12/83    100
 BRANCH USE-   ROADWAY    [FROM]- N CURB A ST               [TO]-N WALL
------------------------------------------------------------------------------
I1AVE*FIRST AVE                       02      SECONDARY AC      711    11/12/83    100
 BRANCH USE-   ROADWAY    [FROM]- S CURB A ST               [TO]-N CURB B ST
------------------------------------------------------------------------------
I1AVE*FIRST AVE                       03      SECONDARY AC     6933    11/13/83    100
 BRANCH USE-   ROADWAY    [FROM]- S CURB B ST               [TO]-W CURB 2 AVE
------------------------------------------------------------------------------
I2AVE*SECOND AVE                      01      PRIMARY   AC     5627    11/13/83    100
 BRANCH USE-   ROADWAY    [FROM]- S CURB B ST               [TO]-S CURB WAR COLL LOT
------------------------------------------------------------------------------
I2AVE*SECOND AVE                      02      SECONDARY AC     1029    11/13/83    100
 BRANCH USE-   ROADWAY    [FROM]- S CURB WAR COLL LOT       [TO]-S CURB
------------------------------------------------------------------------------
I3AVE*THIRD AVE                       01      PRIMARY   AC     1791    11/13/83     97
 BRANCH USE-   ROADWAY    [FROM]- S CURB M ST               [TO]-N CURB B ST
------------------------------------------------------------------------------
I3AVE*THIRD AVE                       02      TERTIARY  AC      952    11/13/83     16
 BRANCH USE-   ROADWAY    [FROM]- N SIDE BLDG 20            [TO]-S SIDE BLDG 21
```

Figure 12 (Cont'd).

```
-------------------------------------------------------------------------------
I3AVE*THIRD AVE                03     TERTIARY  AC     252    11/13/83    19
 BRANCH USE-  ROADWAY   [FROM]- E CURB I3AVE02        [TO]-E CURB I3AVE02
-------------------------------------------------------------------------------
I4AVE*FOURTH AVE               01     SECONDARY AC     1350   11/13/83   100
 BRANCH USE-  ROADWAY   [FROM]- N CURB B ST           [TO]-N SIDE BLDG 31
-------------------------------------------------------------------------------
I4AVE*FOURTH AVE               02     PRIMARY   AC     6471   11/13/83    66
 BRANCH USE-  ROADWAY   [FROM]- S WALL AT RIVER       [TO]-S CURB B ST
-------------------------------------------------------------------------------
I4AVE*FOURTH AVE               03     TERTIARY  AC     125    11/13/83    52
 BRANCH USE-  ROADWAY   [FROM]- WAR COLLEGE           [TO]-W CURB I4AVE02
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                01     SECONDARY AC     774    11/12/83   100
 BRANCH USE-  ROADWAY   [FROM]- LAMP POST B & 5       [TO]-268' N END CURB E
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                02     SECONDARY AC     400    11/12/83    91
 BRANCH USE-  ROADWAY   [FROM]- S CURB B ST           [TO]-200' S S CURB B
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                03     SECONDARY AC     1222   11/12/83    84
 BRANCH USE-  ROADWAY   [FROM]- N CURB GATE 2 ST      [TO]-E CURB 4TH AVE
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                04     TERTIARY  AC     740    11/18/83   100
 BRANCH USE-  ROADWAY   [FROM]- W CURB 5 AVE          [TO]-W CURB 5 AVE
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                05     TERTIARY  AC     394    11/12/83    78
 BRANCH USE-  ROADWAY   [FROM]- E CURB 4 AVE          [TO]-W CURB 5 AVE
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                06     SECONDARY AC     600    11/12/83    67
 BRANCH USE-  ROADWAY   [FROM]- 200' S OF B ST        [TO]-500' S OF B ST
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                07     SECONDARY AC     1140   11/12/83    87
 BRANCH USE-  ROADWAY   [FROM]- 500' S OF B ST        [TO]-N SIDE POOL LOT
-------------------------------------------------------------------------------
I5AVE*FIFTH AVE                08     SECONDARY AC     1786   11/12/83    33
 BRANCH USE-  ROADWAY   [FROM]- N SIDE POOL LOT       [TO]-N CURB AT GATE 2 ST
```

Figure 12 (Cont'd).

```
                             PCI FREQUENCY REPORT
AGENCY NAME: FT. MCNAIR                           REPORT DATE:  85/03/13.

BRANCH USE: MTRPOOL STORAGE ROADWAY PARKING RUNWAY  APRON   HELIPAD TAXIWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC  PCC
ZONE         : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N
                             TABLE OF PCI FREQUENCIES
                                  YR= 1985/03
    CONDITION    PCI RANGE   NO OF SECTIONS    % OF SECTIONS
    FAILED         0 -  10         5               6.58
    V.POOR        11 -  25         6               7.89
    POOR          26 -  40         4               5.26
    FAIR          41 -  55         9              11.84
    GOOD          56 -  70         6               7.89
    V.GOOD        71 -  85         6               7.89
    EXCEL         86 - 100        40              52.63

   TOTAL NO. OF SECTION:     76
   AVERAGE PCI:              70
   NO. OF MISSING VALUE:      0


                             PCI FREQUENCY REPORT
AGENCY NAME: FT. MCNAIR                           REPORT DATE:  85/03/13.

BRANCH USE: MTRPOOL STORAGE ROADWAY PARKING RUNWAY  APRON   HELIPAD TAXIWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC  PCC
ZONE         : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N

                                  YR= 1985/03

 NO.
SEC.       CONDITION
                      !
                      !
  5   6.58% FAILED    !*******
                      !
                      !
  6   7.89% V.POOR    !********
                      !
                      !
  4   5.26% POOR      !*****
                      !
                      !
  9  11.84% FAIR      !************
                      !
                      !
  6   7.89% GOOD      !********
                      !
                      !
  6   7.89% V.GOOD    !********
                      !
                      !
 40  52.63% EXCEL     !********************************************************
                      !
                      !
----                  !-------------!-------------!-------------!-------------!
 76                   0            10            20            30            40

                                                 NO. OF SECTIONS


  TOTAL NO. OF SECTION:     76
  AVERAGE PCI:              70
  NO. OF MISSING VALUE:      0
```

Figure 13. Frequency (FREQ) report for present-year conditions.

PCI FREQUENCY REPORT

AGENCY NAME: FT. MCNAIR REPORT DATE: 85/03/13.

BRANCH USE: MTRPOOL STORAGE ROADWAY PARKING RUNWAY APRON HELIPAD TAXIWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC PCC
ZONE : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N

LIST OF SECTIONS IN
PCI FREQ REPORT
YR= 1985/03

BRANCH NUMBER	BRANCH USE	SECT. NO.	CUR PCI	PRO PCI	---FROM---	---TO---
P5AVE	PARKING	01	77	0	S EDGE B STR	205' S OF B STR
PB042	PARKING	01	81	0	E WALL BLDG 44	E CURB 1ST AVE
PB050	PARKING	01	80	0	N SIDE OF TREE	SW CORNER BLDG 50
I5AVE	ROADWAY	02	91	0	S CURB B ST	200' S S CURB B
I3AVE	ROADWAY	02	16	8	N SIDE BLDG 20	S SIDE BLDG 21
I3AVE	ROADWAY	03	19	11	E CURB I3AVE02	E CURB I3AVE02
PB046	PARKING	01	95	15	NE CORNER BLDG 46	NW CORNER BLDG 46
P5AVE	PARKING	04	24	16	75' N OF GATE 2 ST	N CURB GATE 2 ST
PB035	PARKING	05	25	20	S SIDE BLDG 35	32' S OF BLDG 35
I5AVE	ROADWAY	08	33	23	N SIDE POOL LOT	N CURB AT GATE 2 ST
ICSTR	ROADWAY	03	32	25	E CURB 3RD AVE	W CURB 5TH ST
P5AVE	PARKING	05	34	27	S END GATE 2	176' S GATE 2
PB017	PARKING	01	40	34	E SIDE 3 AVE	30' E 3 AVE
P5AVE	PARKING	02	42	36	35' S OF BLDG 28	855' S BLDG 28
PDOCK	PARKING	01	43	37	N DOCK WALL BLDG 59	S DOCK WALL BLDG 59
P5AVE	PARKING	03	47	42	S SIDE C STR	166' S OF S SIDE C
IBSTR	ROADWAY	01	48	43	W WALL	W CURB 2 AVE
I4AVE	ROADWAY	03	52	47	WAR COLLEGE	W CURB I4AVE02
IBSTR	ROADWAY	03	52	47	N CURB B ST 02	N CURB B ST 02
PB035	PARKING	04	54	49	WALL E SIDE	84' W OF E
PB039	PARKING	01	90	50	S EDGE A STR	S WALL BLDG 39
PB041	PARKING	01	90	50	W WALL BLDG 45	W EDGE FOURTH AVE
PB022	PARKING	01	58	54	N WALL BLDG 22	S WALL BLDG 22
IESTR	ROADWAY	02	93	55	N EDGE E ST CIRCLE	S WALL WAR COLLEGE
PCSTR	PARKING	02	62	58	20' E OF 4TH ST	5TH ST
PB031	PARKING	02	64	61	E SIDE BLDG 31	24' E BLDG 31
PB031	PARKING	01	91	62	18' W BLDG 31	E SIDE BLDG 35
I4AVE	ROADWAY	02	66	62	S WALL AT RIVER	S CURB B ST
I5AVE	ROADWAY	06	67	63	200' S OF B ST	500' S OF B ST
PB035	PARKING	02	93	70	E SIDE BLDG 35	WALL E OF BLDG 35
IBSTR	ROADWAY	04	81	73	45' E E CURB 3AVE	E CURB 4AVE
I5AVE	ROADWAY	05	78	75	E CURB 4 AVE	W CURB 5 AVE
I5AVE	ROADWAY	03	84	82	N CURB GATE 2 ST	E CURB 4TH AVE
PPLOT	PARKING	01	85	83	S CURB 5 AVE	E CURB 4 AVE
PSLIP	PARKING	01	86	84	BLDG 23	BLDG 26
I5AVE	ROADWAY	07	87	85	500' S OF B ST	N SIDE POOL LOT
PB035	PARKING	01	98	90	E SIDE BLDG 35	W SIDE BLDG 35
I1AVE	ROADWAY	01	100	95	N CURB A ST	N WALL
I2AVE	ROADWAY	01	100	95	S CURB B ST	S CURB WAR COLL LOT
I3AVE	ROADWAY	01	97	95	S CURB M ST	N CURB B ST
I4AVE	ROADWAY	01	100	95	N CURB B ST	N SIDE BLDG 31
I5AVE	ROADWAY	01	100	95	LAMP POST B & 5	268' N END CURB E
IACCE	ROADWAY	01	100	95	N SIDE BLD 48 ANNEX	10' S BLDG 50
IASTR	ROADWAY	01	100	95	15' E W BLDG 48	W CURB 1 AVE
ICSTR	ROADWAY	01	100	95	E CURB 1AVE	W CURB 2AVE
IDSTR	ROADWAY	01	100	95	W CURB 4AVE	E CURB 2AVE
IESTR	ROADWAY	01	100	95	14' E E CURB 2AVE	W CURB 4AVE
P1AVE	PARKING	01	100	95	NW CORNER BLDG 58	5' N B STR
PASTR	PARKING	01	100	95	W EDGE A STR	W CURB 1ST AVE
PB018	PARKING	01	100	95	E SIDE PLAY YARD	FIFTH AVE

Figure 13 (Cont'd).

BRANCH NUMBER	BRANCH USE	SECT. NO.	CUR PCI	PRO PCI	---FROM---	---TO---
PB029	PARKING	01	100	95	20' W BLDG 31	6' E BLDG 29
PB034	PARKING	01	100	95	SW CORNER BLDG 34	W WALL BLDG 32
PB047	PARKING	01	100	95	W WALL BLDG 47	E WALL BLDG 47
PB052	PARKING	01	100	95	W BLDG 52	E BLDG 52
PB056	PARKING	01	100	95	65'N OF B ST	N CURB B ST
PBWAR	PARKING	01	100	95	BRICK PAVEMENT	W CURB 4 AVE
PCSTR	PARKING	01	100	95	20'W W CURB 3 AVE	26'E E CURB 2 AVE
PDSTR	PARKING	01	100	95	80'W W CURB 4 AVE	350'W W CURB 4 AVE
PPARK	PARKING	01	100	95	N EDGE BASE	389' S OF N EDGE
PPOOL	PARKING	01	100	95	SW N SIDE	215' S OF N
I1AVE	ROADWAY	02	100	95	S CURB A ST	N CURB B ST
I2AVE	ROADWAY	02	100	95	S CURB WAR COLL LOT	S CURB
IASTR	ROADWAY	02	100	95	W CURB 3 AVE	100'S N SIDE BLD 48
IBSTR	ROADWAY	02	100	95	W CURB 2 AVE	45'E E CURB 3 AVE
ICSTR	ROADWAY	02	99	95	E CURB 2AVE	W CURB 3AVE
PASTR	PARKING	02	100	95	NW CORNER BLDG 48	S EDGE A STR
PB018	PARKING	02	100	95	S OF SE COR BLDG 18	10' W 5TH STR
PB034	PARKING	02	100	95	NE CORNER BLDG 34	E WALL BLDG 36
PB046	PARKING	02	100	95	SE CORNER BLDG 46	W CURB FIRST AVE
PB050	PARKING	02	100	95	NE CORNER BLDG 50	NW CORNER BLDG 50
PBWAR	PARKING	02	100	95	E CURB 2 AVE	BRICK PAVEMENT
I1AVE	ROADWAY	03	100	95	S CURB B ST	W CURB 2 AVE
IASTR	ROADWAY	03	100	95	15' E OF BLDG 31	E CURB 3RD AVE
PB035	PARKING	03	100	95	4 AVE E EDGE E SW	WALL E SIDE
I5AVE	ROADWAY	04	100	95	W CURB 5 AVE	W CURB 5 AVE
IBSTR	ROADWAY	05	100	95	E CURB 4AVE	CURB E END

TOTAL NO. OF SECTION: 76
AVERAGE PCI: 70
NO. OF MISSING VALUE: 0

Figure 13 (Cont'd).

Program-Year Conditions

One of the main goals of pavement management is to predict the need for major repairs well before actual need. The time when repairs are accomplished in relation to current PCIs, sections could be below their acceptable minimum PCI for several months or years just because of the normal lead time required for a major repair project to be identified and the work actually done. Not only will this cause pavement sections to be in a state of disrepair, but the eventual repair costs will be much higher than necessary. The solution lies in accounting for the project lead time in the management process by projecting the current section PCIs to the program year. This is done with the FREQ report. Figure 14 displays a FREQ report for the program year.

Evaluating Inspected Sections

After the network inspections are completed, the inspection results should be evaluated to identify problem sections. Sections that indicate a change in the cause of distresses, rate of deterioration, or extent of deterioration should be identified for further analysis.

The sections should be evaluated on a section-by-section basis since each section is an individual unit in terms of construction history, structural section, and traffic. The Section Evaluation Summary provides a consistent method for this evaluation. Figure 15 provides an example, and the following discussion explains the preparation of the report. Chapter 4 of TM 5-623 and Chapter 4 of USA-CERL Technical Report M-294 provide the reference for Figure 15 and provide further discussion on section evaluation.

```
                              PCI FREQUENCY REPORT
AGENCY NAME: FT. MCNAIR                          REPORT DATE:  85/03/13.

BRANCH USE: MTRPOOL STORAGE ROADWAY PARKING RUNWAY  APRON   HELIPAD TAXIWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC  PCC
ZONE         : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N
                              TABLE OF PCI FREQUENCIES
                                   YR= 1988/03
     CONDITION    PCI RANGE   NO OF SECTIONS    % OF SECTIONS
     FAILED         0 -  10         14              18.42
     V.POOR        11 -  25          6               7.89
     POOR          26 -  40          5               6.58
     FAIR          41 -  55          2               2.63
     GOOD          56 -  70          4               5.26
     V.GOOD        71 -  85          6               7.89
     EXCEL         86 - 100         39              51.32

   TOTAL NO. OF SECTION:     76
   AVERAGE PCI:              58
   NO. OF MISSING VALUE:      0


                              PCI FREQUENCY REPORT
AGENCY NAME: FT. MCNAIR                          REPORT DATE:  85/03/13.

BRANCH USE: MTRPOOL STORAGE ROADWAY PARKING RUNWAY  APRON   HELIPAD TAXIWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC  PCC
ZONE         : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N

                                   YR= 1988/03
 NO.
SEC.        CONDITION
                          !
                          !
  14  18.42% FAILED       !*******************
                          !
                          !
   6   7.89% V.POOR       !********
                          !
                          !
   5   6.58% POOR         !*******
                          !
                          !
   2   2.63% FAIR         !**
                          !
                          !
   4   5.26% GOOD         !*****
                          !
                          !
   6   7.89% V.GOOD       !********
                          !
                          !
  39  51.32% EXCEL        !******************************************************
                          !
                          !
----                      !-------------!-------------!-------------!-------------!
  76                      0            10            20            30             0

                                                  NO. OF SECTIONS

   TOTAL NO. OF SECTION:     76
   AVERAGE PCI:              58
   NO. OF MISSING VALUE:      0


                              PCI FREQUENCY REPORT
AGENCY NAME: FT. MCNAIR                          REPORT DATE:  85/03/13.

BRANCH USE: MTRPOOL STORAGE ROADWAY PARKING RUNWAY  APRON   HELIPAD TAXIWAY
PAVEMENT RANK: P S T X N
SURFACE TYPE: AC  PCC
ZONE         : FTMN
SECTION CATEGORY: A B C D E F G I J K Y N
                         LIST OF SECTIONS IN
                         PCI FREQ REPORT
                            YR= 1988/03

BRANCH     BRANCH    SECT.    CUR  PRO   ---FROM---          ---TO---
NUMBER      USE      NO.      PCI  PCI
P5AVE     PARKING     01       77    0   S EDGE B STR        205' S OF B STR
PB031     PARKING     01       91    0   18' W BLDG 31       E SIDE BLDG 35
PB039     PARKING     01       90    0   S EDGE A STR        S WALL BLDG 39
```

Figure 14. Frequency (FREQ) report for program-year conditions.

BRANCH NUMBER	BRANCH USE	SECT. NO.	CUR PCI	PRO PCI	---FROM---	---TO---
PB041	PARKING	01	90	0	W WALL BLDG 45	W EDGE FOURTH AVE
PB042	PARKING	01	81	0	E WALL BLDG 44	E CURB 1ST AVE
PB046	PARKING	01	95	0	NE CORNER BLDG 46	NW CORNER BLDG 46
PB050	PARKING	01	80	0	N SIDE OF TREE	SW CORNER BLDG 50
I3AVE	ROADWAY	02	16	0	N SIDE BLDG 20	S SIDE BLDG 21
I5AVE	ROADWAY	02	91	0	S CURB B ST	200' S S CURB B
IESTR	ROADWAY	02	93	0	N EDGE E ST CIRCLE	S WALL WAR COLLEGE
I3AVE	ROADWAY	03	19	0	E CURB I3AVE02	E CURB I3AVE02
P5AVE	PARKING	04	24	1	75' N OF GATE 2 ST	N CURB GATE 2 ST
I5AVE	ROADWAY	08	33	2	N SIDE POOL LOT	N CURB AT GATE 2 ST
ICSTR	ROADWAY	03	32	10	E CURB 3RD AVE	W CURB 5TH ST
PB035	PARKING	05	25	11	S SIDE BLDG 35	32' S OF BLDG 35
P5AVE	PARKING	05	34	14	S END GATE 2	176' S GATE 2
PB017	PARKING	01	40	20	E SIDE 3 AVE	30' E 3 AVE
PB035	PARKING	02	93	20	E SIDE BLDG 35	WALL E OF BLDG 35
P5AVE	PARKING	02	42	24	35' S OF BLDG 28	855' S BLDG 28
PDOCK	PARKING	01	43	25	N DOCK WALL BLDG 59	S DOCK WALL BLDG 59
P5AVE	PARKING	03	47	31	S SIDE C STR	166' S OF S SIDE C
IBSTR	ROADWAY	01	48	32	W WALL	W CURB 2 AVE
IBSTR	ROADWAY	03	52	36	N CURB B ST 02	N CURB B ST 02
I4AVE	ROADWAY	03	52	37	WAR COLLEGE	W CURB I4AVE02
PB035	PARKING	04	54	39	WALL E SIDE	84' W OF E
PB022	PARKING	01	58	45	N WALL BLDG 22	S WALL BLDG 22
PCSTR	PARKING	02	62	50	20' E OF 4TH ST	5TH ST
I4AVE	ROADWAY	02	66	56	S WALL AT RIVER	S CURB B ST
IBSTR	ROADWAY	04	81	56	45' E E CURB 3AVE	E CURB 4AVE
PB031	PARKING	02	64	57	E SIDE BLDG 31	24' E BLDG 31
I5AVE	ROADWAY	06	67	57	200' S OF B ST	500' S OF B ST
I5AVE	ROADWAY	05	78	71	E CURB 4 AVE	W CURB 5 AVE
PB035	PARKING	01	98	72	E SIDE BLDG 35	W SIDE BLDG 35
PPLOT	PARKING	01	85	78	S CURB 5 AVE	E CURB 4 AVE
I5AVE	ROADWAY	03	84	79	N CURB GATE 2 ST	E CURB 4TH AVE
PSLIP	PARKING	01	86	81	BLDG 23	BLDG 26
I5AVE	ROADWAY	07	87	81	500' S OF B ST	N SIDE POOL LOT
I1AVE	ROADWAY	01	100	86	N CURB A ST	N WALL
I2AVE	ROADWAY	01	100	86	S CURB B ST	S CURB WAR COLL LOT
I4AVE	ROADWAY	01	100	86	N CURB B ST	N SIDE BLDG 31
I5AVE	ROADWAY	01	100	86	LAMP POST B & 5	268' N END CURB E
IACCE	ROADWAY	01	100	86	N SIDE BLD 48 ANNEX	10' S BLDG 50
IASTR	ROADWAY	01	100	86	15' E W BLDG 48	W CURB 1 AVE
ICSTR	ROADWAY	01	100	86	E CURB 1AVE	W CURB 2AVE
IDSTR	ROADWAY	01	100	86	W CURB 4AVE	E CURB 2AVE
IESTR	ROADWAY	01	100	86	14' E E CURB 2AVE	W CURB 4AVE
P1AVE	PARKING	01	100	86	NW CORNER BLDG 58	5' N B STR
PASTR	PARKING	01	100	86	W EDGE A STR	W CURB 1ST AVE
PB018	PARKING	01	100	86	E SIDE PLAY YARD	FIFTH AVE
PB029	PARKING	01	100	86	20' W BLDG 31	6' E BLDG 29
PB034	PARKING	01	100	86	SW CORNER BLDG 34	W WALL BLDG 32
PB047	PARKING	01	100	86	W WALL BLDG 47	E WALL BLDG 47
PB052	PARKING	01	100	86	W BLDG 52	E BLDG 52
PB056	PARKING	01	100	86	65'N OF B ST	N CURB B ST
PBWAR	PARKING	01	100	86	BRICK PAVEMENT	W CURB 4 AVE
PCSTR	PARKING	01	100	86	20'W W CURB 3 AVE	26'E E CURB 2 AVE
PDSTR	PARKING	01	100	86	80'W W CURB 4 AVE	350'W W CURB 4 AVE
PPARK	PARKING	01	100	86	N EDGE BASE	389' S OF N EDGE
PPOOL	PARKING	01	100	86	SW N SIDE	215' S OF N
I1AVE	ROADWAY	02	100	86	S CURB A ST	N CURB B ST
I2AVE	ROADWAY	02	100	86	S CURB WAR COLL LOT	S CURB
IASTR	ROADWAY	02	100	86	W CURB 3 AVE	100'S N SIDE BLD 48
IBSTR	ROADWAY	02	100	86	W CURB 2 AVE	45'E E CURB 3 AVE
ICSTR	ROADWAY	02	99	86	E CURB 2AVE	W CURB 3AVE
PASTR	PARKING	02	100	86	NW CORNER BLDG 48	S EDGE A STR
PB018	PARKING	02	100	86	S OF SE COR BLDG 18	10' W 5TH STR
PB034	PARKING	02	100	86	NE CORNER BLDG 34	E WALL BLDG 36
PB046	PARKING	02	100	86	SE CORNER BLDG 46	W CURB FIRST AVE
PB050	PARKING	02	100	86	NE CORNER BLDG 50	NW CORNER BLDG 50
PBWAR	PARKING	02	100	86	E CURB 2 AVE	BRICK PAVEMENT
I1AVE	ROADWAY	03	100	86	S CURB B ST	W CURB 2 AVE
IASTR	ROADWAY	03	100	86	15' E OF BLDG 31	E CURB 3RD AVE
PB035	PARKING	03	100	86	4 AVE E EDGE E SW	WALL E SIDE
I5AVE	ROADWAY	04	100	86	W CURB 5 AVE	W CURB 5 AVE
IBSTR	ROADWAY	05	100	86	E CURB 4AVE	CURB E END
I3AVE	ROADWAY	01	97	92	S CURB M ST	N CURB B ST

TOTAL NO. OF SECTION: 76
AVERAGE PCI: 58
NO. OF MISSING VALUE: 0

Figure 14 (Cont'd).

SECTION EVALUATION SUMMARY

For use of this form, see TM 5-623: the proponent agency is USACE

1. Overall Condition Rating--PCI ______

Rating-- PCI	Failed, 0-10	Very Poor, 11-25	Poor, 26-40	Fair, 41-55	Good, 56-70	Very Good, 71-85	Excellent 86-100

2. Variation of Condition Within Section -- PCI

   a. Localized Random Variation — Yes, No
   b. Systematic Variation — Yes, No

3. Rate of Deterioration of Condition -- PCI

   a. Long-term period (since construction or last overall repair) — Low, Normal, High
   b. Short-term period (1 year) — Low, Normal, High

4. Distress Evaluation

   a. Cause

   Load Associated Distress — ___ percent deduct value
   Climate/Durability Associated — ___ percent deduct value
   Other(___) Associated Distress — ___ percent deduct value

   b. Moisture (Drainage) Effect on Distress — Minor, Moderate, Major

5. Deficiency of Load-Carrying Capacity — No, Yes

6. Surface Roughness — Minor, Moderate, Major

7. Skid Resistance/Hydroplaning Potential — Minor, Moderate, Major

8. Previous Maintenance — Low, Normal, High

9. Comments: ____

____
____
____
____
____
____

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Figure 15. Section evaluation summary.

Type and Extent of Deterioration

The deterioration of the network and of individual sections should be analyzed in three areas: (1) PCI, (2) location of distresses in the section, and (3) types and location of distresses within the pavement structure.

The overall extent of deterioration is directly related to the PCI and should be evaluated both on the network level and on an individual section basis. At the network level, if the network is small and sections vary greatly in size, the average PCI/sq yd should be compared with previous inspections to determine the net change. The PCI/sq yd (SY) can be determined by using the equation:

$$\frac{PCI}{SY} = \sum_{i=1}^{n} \frac{PCI(i)*A(i)}{\sum_{i=1}^{n} A(i)} \qquad \text{[Eq 1]}$$

where: n = total number of sections in the network PCI
PCI(i) = PCI of each section
A(i) = total area of each section.

This average PCI/sq yd is recommended to the mean section PCI for networks with few sections and/or where sections vary in size considerably, because it accounts for the variation in section size. By deriving a PCI/sq yd for various pavement ranks or geographic areas, a user can evaluate smaller groups or areas. Calculating the PCI/sq yd is not done within PAVER, but it can be calculated manually or even more easily if a spreadsheet software package such as LOTUS is used with the microcomputer on which PAVER is run. Columns representing section identification, section areas, and current or projected section PCIs can be entered and stored. The software package can then perform the calculations. Lacking the spreadsheet software, the calculations can be performed manually (see Table 3). Mean section PCIs are obtained from the FREQ report. This value is the "Average PCI" displayed in the report (see Figure 13).

The network average PCI will also be a good indicator of the cost to repair the overall network, with the lower PCIs representing higher unit costs for repair and a larger number of sections needing repair. This figure will play a key role in budget strategy comparisons. On an individual section basis, the average PCI will help determine the repair strategy, priority, and cost to repair.

The location of distress within the section will determine if the entire section should be repaired or if localized areas within the section should receive special consideration. Sections that show localized or systematic variation should receive additional analysis. Systematic variation is distress that follows a specific pattern either throughout or over a large portion of the section (e.g., one pavement lane shows structural deterioration while the other does not). Localized variation is a small bad area that is not typical of the rest of the section (e.g., a poorly compacted utility trench that has led to pavement deterioration). Systematic and localized variation indicates that one portion of a section is not behaving like the rest of it. Sections displaying variation will require careful evaluation at the project level (see Chapter 4).

The pavement layer where the distress originates will play a large role in deciding which repair alternative will be applied. Although the distress can be seen at the surface, the nature of the problem may be more deep-seated. The climate/durability-related distresses, which are usually confined to the surface or the surface course, include bleeding, longitudinal and transverse cracking, weathering, and raveling. Load-

Table 3

Example Network and Section PCI Calculations

Branch Number (BN)	Section Number (SN)	Area (SY)	1984 PCI PCI-Area	1985 PCI PCI-Area	1986 PCI PCI-Area	1987 PCI PCI-Area	1988 PCI PCI-Area	1989 PCI PCI-Area
I12AW	01	287	100 28700	97 27839	94 26978	91 26117	88 25226	85 24395
I12SQ	01	314	100 31400	97 30458	94 29516	91 28574	88 27632	85 26690
I14AW	01	322	0 0	100 32200	97 31234	94 30268	91 29302	88 28336
P1600	01	951	100 95100	96 91296	92 87492	88 83688	84 79884	80 76080
P0106	02	2347	0 0	0 0	100 234700	96 225312	92 215924	88 206536
PW12A	01	236	100 23600	96 22656	92 21712	88 20768	84 19824	80 18880
II0WA	02	642	15 8630	100 64200	97 62274	94 60348	91 58422	88 56496
P210B	01	3030	17 51510	13 39390	9 27270	100 303000	96 290880	92 278760
P2023	04	1411	100 141100	96 135456	92 129812	88 124168	84 118524	80 112880
P210B	02	2100	100 210000	96 201600	92 193200	88 184800	84 176400	80 168000
PCONF	02	4371	35 152985	100 437100	96 419616	92 402132	88 384648	84 367164
IAR11	01	820	43 35260	33 27060	23 18860	13 10660	100 82000	97 79540
I13AW	01	310	58 17980	56 17360	54 16740	53 16430	51 15810	49 15190
P3223	01	2047	57 116679	52 106440	46 94162	41 83907	100 204700	96 196512

Table 3 (Cont'd)

Branch Number (BN)	Section Number (SN)	Area (SY)	1984 PCI PCI-Area	1985 PCI PCI-Area	1986 PCI PCI-Area	1987 PCI PCI-Area	1988 PCI PCI-Area	1989 PCI PCI-Area
P0103	01	9682	64 299648	60 280920	56 262192	52 243464	48 224736	44 206008
II0WA	01	3746	69 258198	67 250714	66 264972	64 239488	63 235746	61 228262
PE88II	01	795	56 44520	47 37365	100 79500	96 76320	92 73140	88 69960
PAR11	01	347	67 23249	58 20473	51 17697	43 14921	100 34700	96 33312
PW01A	01	7423	73 541879	72 534456	70 519610	69 512187	67 497341	66 489918
IWALB	01	858	75 64350	74 63492	73 62634	71 60918	70 60060	69 59202
PAR11	02	365	67 24455	56 20440	46 16790	100 36500	96 35040	92 33580
P0104	01	2577	81 208757	80 206160	79 203583	78 201006	77 198429	76 195852
IR45E	01	392	61 23912	48 18816	100 39200	96 38024	92 36848	88 34496
IR45N	01	60	85 5100	84 5040	82 4920	81 4960	79 4740	78 4680
LAR11	02	633	91 57603	90 50970	89 56337	88 55704	87 55071	86 54438
P2023	03	1974	98 193452	98 198452	97 191478	97 191478	96 189504	96 189504
		43,036	2,658,267	2,920,353	3,112,479	3,275,142	3,374,531	3,254,671
	Average	PCI/SY	62	68	72	76	78	76

Note: Normal rates of deterioration representative of the actual network were assumed.

related distresses, such as alligator cracking, depressions, rutting, and corrugation, are caused by excessive traffic loads. When these distresses appear, at least one layer in the pavement structure has already begun to fail. A structural failure will involve not only the surface course but also the base and possibly the subbase and subgrade. This type of failure is far more expensive to repair because it involves removing failed layers and replacing them with new materials.

Deterioration Rate

Deterioration rate is an important part of determining network and project priorities. The Condition History (CNDHIST) report (Figure 16) graphically represents the past performance of each section. Sections that continue to show a high rate of deterioration should be flagged for more analysis. Depending on the cause of the deterioration, a number of maintenance/repair alternatives to reduce the rate will have to be studied.

Low, medium, and high deterioration rates must be determined from local data and experience. For each pavement use/pavement rank combination, the PCI should be plotted against the age since last overlay or construction. Based on the scatter of points, an envelope can be developed to determine the break point between low and medium and between medium and high (see Figure 17). Also, see TM 5-623 or USA-CERL Technical Report M-294. This curve can be established after the first PCI inspection. For illustrative purposes, the envelopes in Figure 17 were plotted from a best fit of the standard deviation of the data points for a specific age (disregarding very limited data from years 9 and 13). Recall, however, that it will be based on *historical* data. Proper pavement management may significantly reduce deterioration rates. Therefore, over time, after preventive maintenance practices have been incorporated, etc., the curves should be redone to reflect the new policies.

Cause of Deterioration

An explanation of the specific distress types, severity, and quantity can provide information about the causes of the pavement section's deterioration. Figures 18 through 21[6] classify the various distress types into four general categories of cause and effect: load, climate/durability, moisture/drainage, and other factors.

To determine the percentage of distress associated with each cause, the total deduct values (TDV) from each cause are summed separately. The percentage of deducts attributed to each cause is then computed. For example, in Figure 22, the distresses and TDV values were measured on a pavement section. The INSPCUR and SAMPCUR reports provide this summary. (See Figures 23 and 24.)

To determine if moisture is accelerating the deterioration, a review of INSPCUR and SAMPCUR reports can provide information about moisture infiltration. Certain distresses such as alligator cracking, edge cracking, potholes, and swelling can be good indicators of excess moisture in either the structure or subgrade. If enough of these distresses occur, some field investigation will be necessary to determine if water is

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[6] M. Y. Shahin, *Development of a Pavement Maintenance Management System, Vol VI: Maintenance and Repair Guidelines -- Validation and Field Applications*, ESL-TR-79-18 (Engineering and Services Laboratory [ESL], Air Force Engineering and Services Center [AFESC], December 1979); Technical Manual 5-623; USA-CERL Technical Report M-294.

```
                          CONDITION HISTORY
AGENCY NAME: CAMERON STATION                 REPORT DATE:  85/02/27.

BRANCH NAME: NEW LOT
BRANCH USE: PARKING
SECTION NUMBER: 02
PAVEMENT RANK: OTHER
SURFACE TYPE: AC
                          DATE           PCI
     CONST/OVERLAY        71/06          100
     INSP                 83/11           54
     PRED                 1989            35

 PCI

100-I*
    I
    I
 80-I
    I
    I
 60-I
    I
    I                        *
 40-I
    I                                 *
    I
 20-I
    I
    I
  0-I
   -I---I---I---I---I---I---I---I---I---I---I---I---I---I---I---
   72  74  76  78  80  82  84  86  88  90  92

                          FISCAL YEAR
```

Figure 16. Condition history (CNDHIST) report.

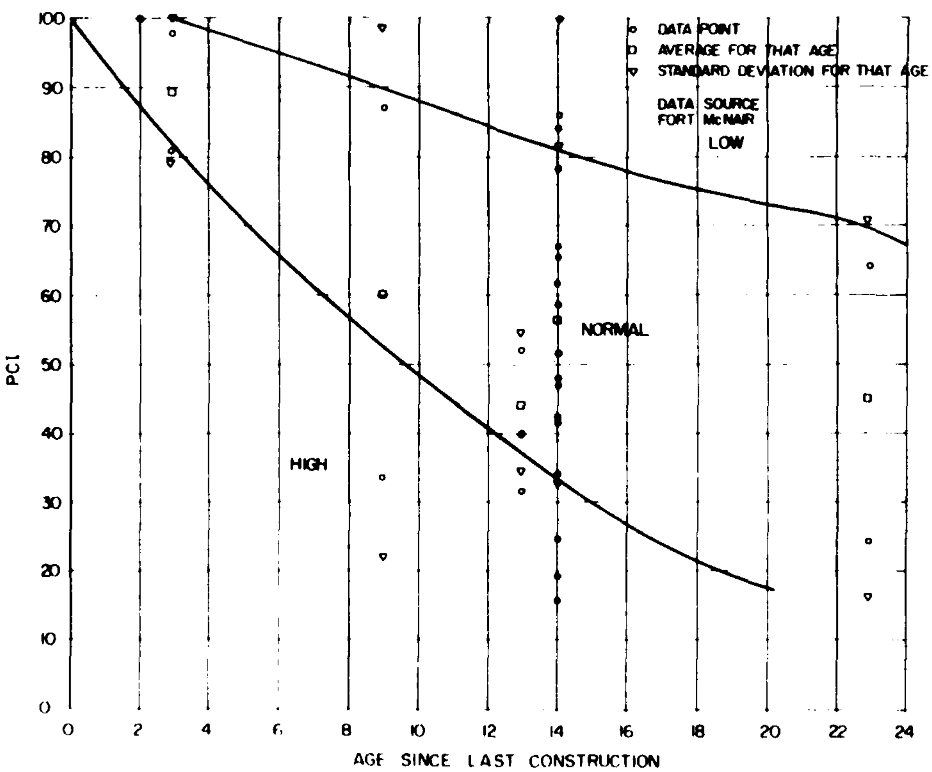

Figure 17. Example PCI versus time plot.

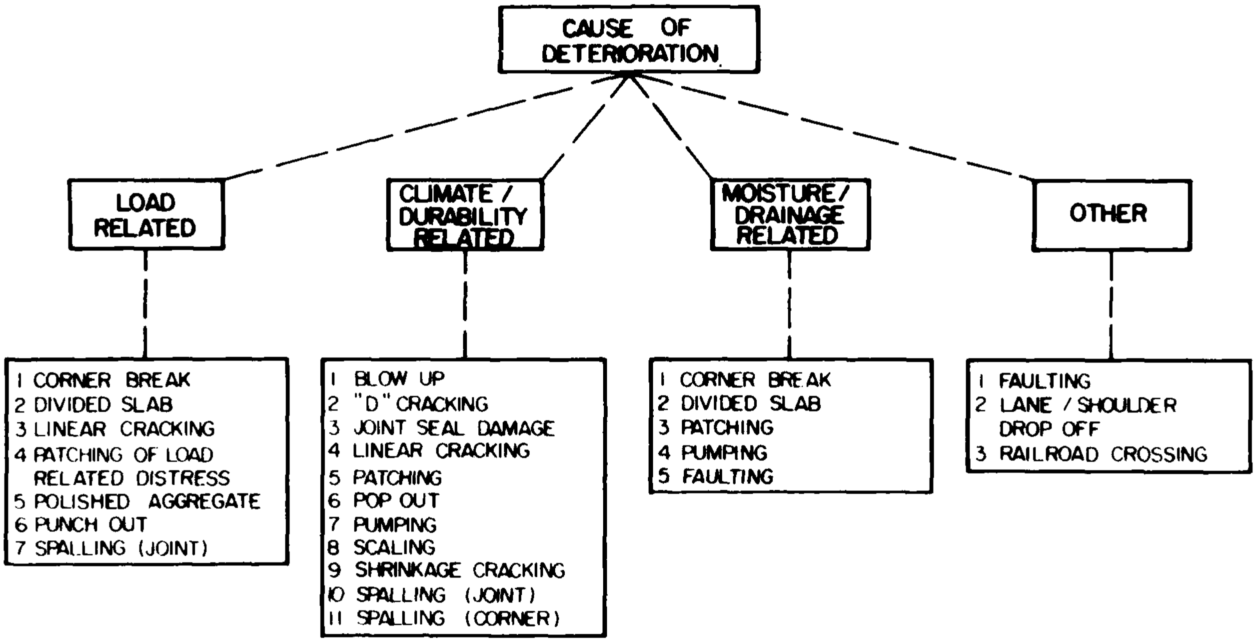

Figure 18. Road and street PCC distress types and likely causes.

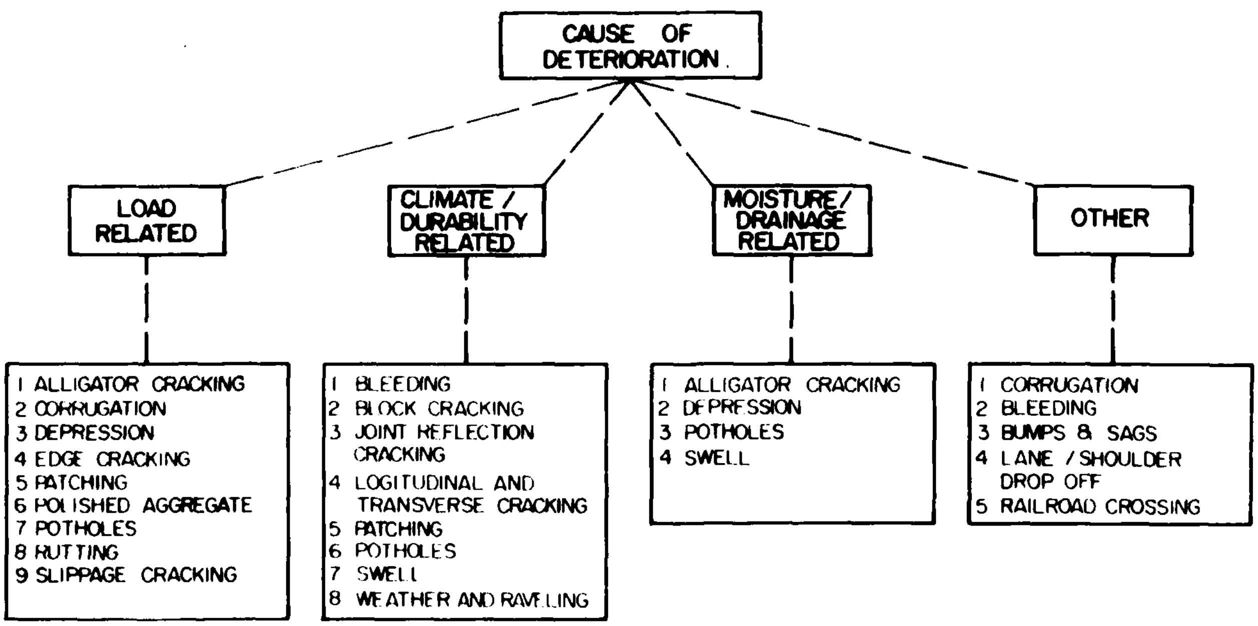

Figure 19. Road and street AC distress types and likely causes.

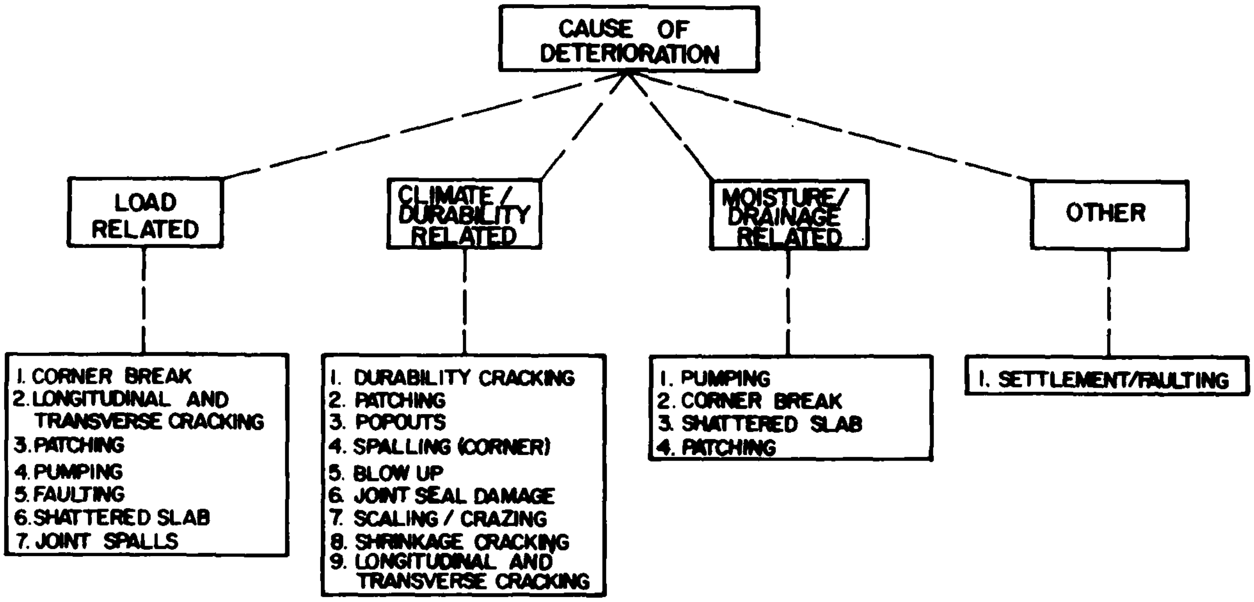

Figure 20. Airfield PCC distress types and likely causes.

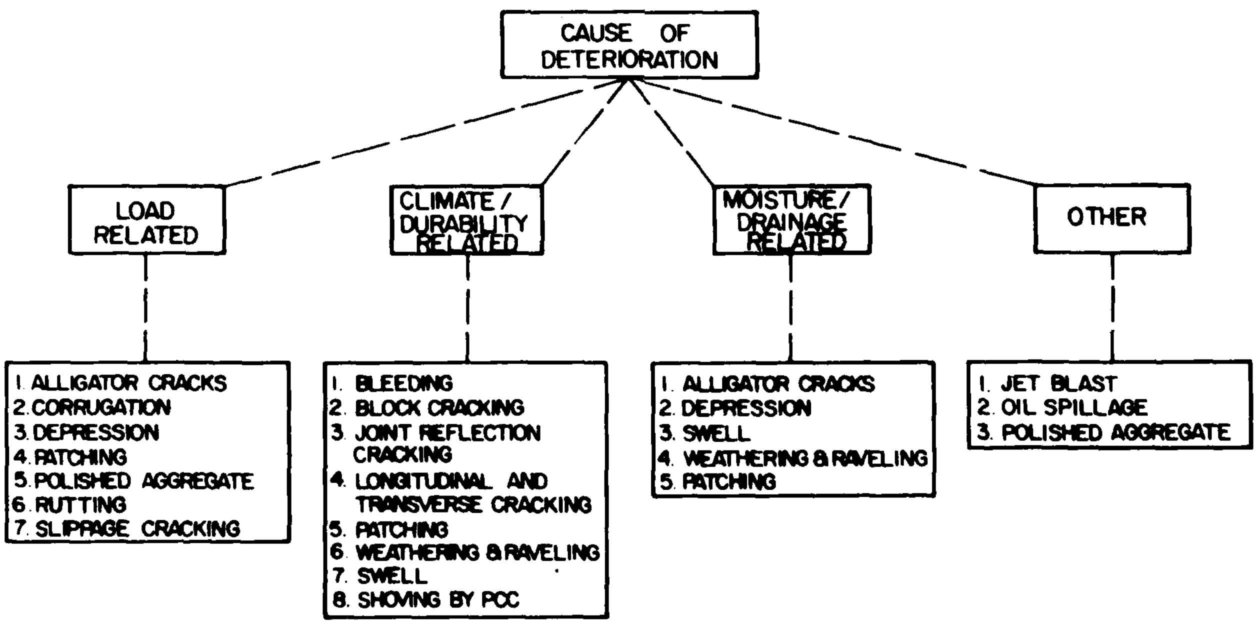

Figure 21. Airfield AC distress types and likely causes.

DISTRESS ANALYSIS

Branch Number IVPAT
Section Number 06

Total Deduct Value		93.4		

Load-Related Distress	Severity	Deduct		
Alligator CR*	Low	42.1		
Edge CR	Low	2.7		
Edge CR	Medium	10.0		
Total of Load-Related Deducts		55.0		
% of Load-Related Distress		55/93.4	=	58.89%

Climate-Related Distress	Severity	Deduct		
Block CR	Low	3.3		
Block CR	Medium	10.0		
Block CR	High	11.8		
Long/Trans CR	Low	3.9		
Long/Trans CR	Medium	0.0		
Total of Climate-Related Distress		29.0		
% of Climate/Durability-Related Distress		29.0/93.4	=	31.05%

Other Distresses	Severity	Deduct		
Depression	Low	4.2		
Lane/Shldr Drop	Medium	5.2		
Total of Other Deducts		9.4		
% of Other Related Distresses		9.4/93.4	=	10.06%

*CR = cracking.

Figure 22. Example distresses and deduct values.

```
REPORT DATE-  03/12/85              PAVEMENT INSPECTION

AGENCY NUMBER =       051855      VINT HILL FARMS STATION

------------------------------------------------------------------------------
BRANCH NAME -   PATROL ROAD                          SECTION LENGTH -       LF
BRANCH NUMBER -  IVPAT                               SECTION WIDTH -      LF
SECTION NUMBER - 06                                  SECTION AREA -    10153 SY
------------------------------------------------------------------------------
INSPECTION DATE - 02/10/84     PCI=  74     RATING=  VERY GOOD
CONDITION- RIDING-1   SAFETY-2   DRAINAGE-1   SHOULDERS-    OVERALL-1

TOTAL NUMBER OF SAMPLES IN SECTION=                              42
NUMBER OF SAMPLES SURVEYED=                                       6
RECOMMENDED SAMPLES TO BE SURVEYED=                              35
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED=       26.6

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-
```

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
01 ALLIGATOR CR	HIGH	2131 SF	2.33	42.1
03 BLOCK CR	HIGH	2145 SF	2.34	11.8
03 BLOCK CR	LOW	3502 SF	3.83	3.3
03 BLOCK CR	MEDIUM	4076 SF	4.46	10.0
06 DEPRESSION	LOW	692 SF	0.75	4.2
07 EDGE CR	LOW	865 LF	0.94	2.9
07 EDGE CR	MEDIUM	1384 LF	1.51	10.0
09 LANE/SHLDR DROP	MEDIUM	1384 LF	1.51	5.2
10 LONG/TRANS CR	LOW	1522 LF	1.66	3.9
10 LONG/TRANS CR	MEDIUM	76 LF	0.08	0.0

```
    *** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

  LOAD                 RELATED DISTRESSES =  58.89 PERCENT DEDUCT VALUES.

  CLIMATE/DURABILITY   RELATED DISTRESSES =  31.05 PERCENT DEDUCT VALUES.

  OTHER                RELATED DISTRESSES =  10.06 PERCENT DEDUCT VALUES.
```

Figure 23. Current inspection (INSPCUR) report.

REPORT DATE- 03/13/85 PAVEMENT INSPECTION

AGENCY NUMBER = 051855 VINT HILL FARMS STATION

BRANCH NAME - PATROL ROAD
BRANCH NUMBER - IVPAT
SECTION NUMBER - 06

SECTION LENGTH - LF
SECTION WIDTH - LF
SECTION AREA - 10153 SY

INSPECTION DATE - 02/10/84 PCI= 74 RATING= VERY GOOD
CONDITION- RIDING-1 SAFETY-2 DRAINAGE-1 SHOULDERS- OVERALL-1

TOTAL NUMBER OF SAMPLES IN SECTION=	42
NUMBER OF SAMPLES SURVEYED=	6
RECOMMENDED SAMPLES TO BE SURVEYED=	35
STANDARD DEVIATION OF PCI BETWEEN RANDOM UNITS SURVEYED=	26.6

SAMPLE UNIT-16 (RANDOM) SAMPLE SIZE- 2200 SF SAMPLE PCI- 88

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
07 EDGE CR	LOW	30 LF	1.36	3.2
10 LONG/TRANS CR	LOW	92 LF	4.18	9.2

SAMPLE UNIT-2 (RANDOM) SAMPLE SIZE- 2200 SF SAMPLE PCI- 89

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
07 EDGE CR	LOW	50 LF	2.27	4.2
10 LONG/TRANS CR	LOW	26 LF	1.18	2.5
10 LONG/TRANS CR	MEDIUM	11 LF	0.50	4.4

SAMPLE UNIT-23 (RANDOM) SAMPLE SIZE- 2200 SF SAMPLE PCI- 73

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
03 BLOCK CR	HIGH	60 SF	2.72	13.1
03 BLOCK CR	LOW	241 SF	10.95	8.8
07 EDGE CR	LOW	10 LF	0.45	2.1
09 LANE/SHLDR DROP	MEDIUM	200 LF	9.09	17.2
10 LONG/TRANS CR	LOW	25 LF	1.13	2.4

SAMPLE UNIT-30 (RANDOM) SAMPLE SIZE- 2200 SF SAMPLE PCI- 84

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
03 BLOCK CR	LOW	100 SF	4.54	4.0
06 DEPRESSION	LOW	100 SF	4.54	8.9
10 LONG/TRANS CR	LOW	27 LF	1.22	2.7

Figure 24. Current sample unit inspection (SAMPCUR) report.

SAMPLE UNIT-37 (RANDOM) SAMPLE SIZE- 2200 SF SAMPLE PCI- 89

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
03 BLOCK CR	LOW	165 SF	7.50	6.5
07 EDGE CR	LOW	35 LF	1.59	3.5
10 LONG/TRANS CR	LOW	50 LF	2.27	5.4

SAMPLE UNIT-9 (RANDOM) SAMPLE SIZE- 2200 SF SAMPLE PCI- 21

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
01 ALLIGATOR CR	HIGH	308 SF	14.00	65.7
03 BLOCK CR	HIGH	250 SF	11.36	30.7
03 BLOCK CR	MEDIUM	589 SF	26.77	25.3
07 EDGE CR	MEDIUM	200 LF	9.09	22.8

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION-

DISTRESS TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT-VALUE
01 ALLIGATOR CR	HIGH	2131 SF	2.33	42.1
03 BLOCK CR	HIGH	2145 SF	2.34	11.8
03 BLOCK CR	LOW	3502 SF	3.83	3.3
03 BLOCK CR	MEDIUM	4076 SF	4.46	10.0
06 DEPRESSION	LOW	692 SF	0.75	4.2
07 EDGE CR	LOW	865 LF	0.94	2.9
07 EDGE CR	MEDIUM	1384 LF	1.51	10.0
09 LANE/SHLDR DROP	MEDIUM	1384 LF	1.51	5.2
10 LONG/TRANS CR	LOW	1522 LF	1.66	3.9
10 LONG/TRANS CR	MEDIUM	76 LF	0.08	0.0

COMMENTS-
ALLIGATOR CRACKING IS IN AREAS OF CROSS TRAFFIC

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD	RELATED DISTRESSES =	58.89 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES =	31.05 PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES =	10.06 PERCENT DEDUCT VALUES.

Figure 24 (Cont'd).

present and how it is entering the pavement section (i.e., by ground water, infiltration of surface water, or ponding). If moisture is contributing to the deterioration, it should be noted and corrected during the rest of the repairs to prevent recurrence.

Other Evaluation Data

Other items that must be included in the pavement evaluation are noted deficiencies of load-carrying capacity, surface roughness, skid resistance, and previous maintenance.

A quick analysis of the pavement's load-carrying capability can be determined from the distress types present. As a rule of thumb, if more than 50 percent of the distress is load-related, it can be assumed that the pavement structure is inadequate to handle the applied load properly. If the loads related to stresses are less than 50 percent *but* have increased significantly since the last inspection, it can also be assumed that a load-carrying deficiency exists. A more detailed structural evaluation must be made when the section is studied at the project level.

Surface roughness is rated by ride quality. If ride quality is poor, surface roughness should be rated as high. This is primarily an operational condition rating.

Skid resistance/hydroplaning potential can be evaluated by noting the occurrence of distresses such as bleeding, polished aggregate, depressions, and rutting. Skid resistance is typically an important factor only on high-speed roads and runways, but the engineer should be sensitive to other potential areas where quick stops are common, such as intersections. If the user feels that these distresses are of sufficient quantity and severity to cause low skid resistance and high hydroplaning potential, the section should be rated as high. Again, a more detailed analysis will be needed at the project level.

Previous maintenance can be determined from installation maintenance records or the Work History (WORKHIS) report if they are available. If they are not available, an indication of previous maintenance can be derived from the amount of patching present in the section. Normal patching is considered to be 1.5 to 3.5 percent (based on total surface area for asphalt surfaces and based on the number of slabs for concrete surfaces). Less than 1.5 percent is considered low and greater than 3.5 percent is considered high.

Selecting Candidate Sections for Major Repair

Once sections have been inspected and evaluated, the engineer-manager must determine which pavement sections are candidates for major repair. These sections will be placed in the annual or long-range repair plans. Generally, PCI by branch use and pavement rank will be used to determine which sections are candidates for major repair. As shown in Figure 25, PCI can provide a very strong indication of repairs that individual pavement sections need.[7]

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[7]M. Y. Shahin, *Development of a Pavement Maintenance Management System, Vol VI: Maintenance and Repair Guidelines — Validation and Field Applications*; M. Y. Shahin, M. I. Darter and S. D. Kohn, *Development of a Pavement Maintenance Management System, Vol III: Maintenance and Repair Guidelines for Airfield Pavements*, AFCEC-TR-44 (AFCEC, 1977).

PCI	RATING	MAINTENANCE/REPAIR STRATEGY
100	EXCELLENT	ROUTINE MAINTENANCE/REPAIRS
85	VERY GOOD	
70	GOOD	ROUTINE MAINTENANCE/REPAIRS, OR MAJOR REPAIRS, OR OVERALL RECONSTRUCTION
55	FAIR	
40	POOR	MAJOR REPAIRS, OR OVERALL RECONSTRUCTION
25	VERY POOR	OVERALL RECONSTRUCTION
10 0	FAILED	

Figure 25. PCI and maintenance/repair matrix.

Minimum Acceptable PCI

Determining the minimum acceptable level of service for the pavement section in the network is a key element of selecting candidate sections for major repair. Once this value (i.e., the minimum acceptable PCI) is determined, it can be assumed that any pavement sections below this level are candidates for major repair and above this level are candidates for prevention or routine maintenance. This generalized assumption is valid when managing at the network level. Whether individual sections are actually repaired at given PCI levels will be determined by the results of the project-level evaluation conducted later in the pavement management process.

Minimum acceptable criteria can be applied to the overall network or subnetwork or to individual sections. Although there is a relationship between network minimum PCIs and section minimum PCIs, they are not the same. Network-level conditions are the average of the individual pavement section conditions. Since conditions can vary greatly among individual pavement sections, the overall network PCI is not a good indicator for determining which pavement sections are candidates for repair. If network PCI were used, depending on the variation between PCIs of individual pavement sections, there could be a number of pavement sections in extremely poor condition even though the overall network PCI might be above the desired minimum. Thus, although network-level PCI should not be used in this case, it is an extremely valuable management tool for studying the effects of implementing strategies and for formulating budgets. Since network PCI is an average of the individual section PCIs, if no individual pavement section is allowed to drop below some minimum, the overall network PCI must be higher. How much higher it will be is a function of the PCI variation among pavement sections.

It must then be determined just what the minimum acceptable PCIs should be for these sections. For simplicity, this is most easily done at the branch-use and pavement-rank levels. For example, it would be expected that runways would have a higher minimum than primary roadways, and that the roadways would have a higher minimum acceptable PCI than parking lots.

Many factors can be considered in determining the minimum acceptable PCI. The two most important are engineering judgment and repair costs.

In this context, engineering judgment is an all-encompassing term that would include criteria such as pavement rank, pavement type, aesthetics, politics, trafficability, and functional use. Accordingly, any PCI value can be used as long as it satisfies the engineer-manager. The cost for repairs is another important consideration, and this can be quantified much more objectively. Several studies have shown that as PCI drops, repair costs rise. (The American Public Works Association[8] has described the reasons for this.) Generally, the cost versus PCI relationship is as shown in Figure 26. Although the actual relationship will vary among installations due to differences in pavement designs, repair methods, and regional cost factors, the curvilinear relationship shown is valid for all cases. Most often, the point of inflection, or that point where the costs rapidly rise, is located somewhere between PCIs of 40 and 80. Since a prime reason for managing pavements is to keep their condition above some minimum level at the lowest possible cost, it is logical that pavements should be repaired before they reach PCI levels at which the costs will rise rapidly.

As a recommended starting point, until the cost versus PCI relationship for different pavement types and pavement ranks is established for a given pavement network, the minimum PCI values shown in Table 4 are recommended.

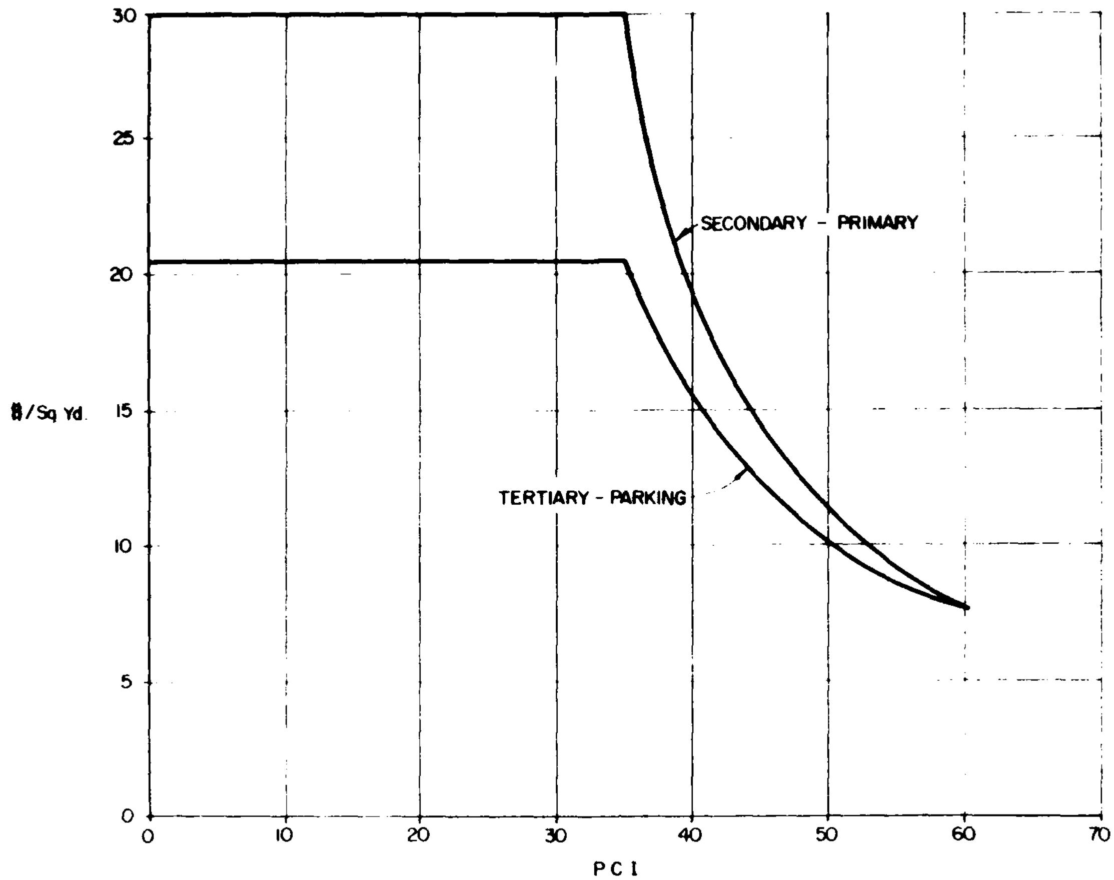
Time-Lapse Considerations

The goal of pavement management will be to repair pavement sections when they just drop below their minimum acceptable PCI. This will minimize repair costs and at the same time maintain their serviceability to a degree that satisfies engineering judgment. To plan for those repairs, projected PCIs, as discussed under *Program-Year Conditions* in this chapter, must be used in the analysis. PCIs must be projected to the time when construction can actually occur. Therefore, all of the lead-time requirements of planning, programming, budgeting, design, and bid execution must be taken into account. For example, if it will be a minimum of 3 years before given pavement sections can be repaired, then those sections that are projected to drop below their minimum acceptable PCIs in 3 years must be considered as candidates for major repair. If the minimum acceptable PCI were applied only to the current year, by the time repairs were made, the PCIs might be well below the minimum, and the cost of repair would be much higher.

Budget Realities

Limited budgets are not a factor in determining which sections are candidates for repair. Clearly, however, limited budgets are the most important factor in determining *when* those sections are repaired. When funds are limited, all pavement sections that are

[8] Christine Johnson, *Pavement (Maintenance) Management Systems* (American Public Works Association, 1983).



PCI vs. COST TO REPAIR

Figure 26. Example PCI versus cost plot.

Table 4

Recommended Minimum Acceptable PCIs

Section Type	PCI
Primary Roadway (main gate)	65
Primary Roadway	60
Secondary Roadway	60
Tertiary Roadway	40
Primary Parking Lot	40
Secondary Parking Lot	30
Primary Runway	70
Secondary Runway	60
Primary Taxiway	60
Secondary Taxiway	50
Primary Apron	50
Secondary Apron	40

now or are projected to be below the minimum acceptable PCI must either be prioritized or optimized* for selecting a time for repairs.

Prioritization and Optimization

If there is a large backlog of sections that are candidates for major repair, a methodology must be established for choosing which ones will be repaired first. This is very important, because repair needs typically exceed available repair funds in a given year. Pavement sections are in a constant state of deterioration, and eventually their condition will drop below the established minimum acceptable PCI, which is when repairs are needed. Strategies tied to budgets can be formulated to eventually reduce or eliminate the backlog, but any time funds are limited, a rational decision must be made about what gets repaired and what gets deferred.

Selection Techniques

Decision-making prioritization or optimization techniques must be used to decide which sections to repair.

Use of prioritization or optimization methods first requires an estimate of cost to repair each section. The estimate can be made on a cost per square yard versus PCI basis (see Figure 26). To estimate the cost for a section, the unit cost must be multiplied by the section area.

Prioritization

Prioritization techniques are easy to use and, consequently, the most popular. There is no one "best" method because the variables used should be the items that are most important to the pavement manager. The simplest method would be to use only PCI. All sections below the minimum acceptable PCI could be ranked, with those having the lowest PCIs being selected first. The FREQ report (Figure 14), which uses the projected PCIs of the program year, can easily be used for this purpose.

Figure 27 shows a second prioritization method.[9] This example combines PCI with pavement rank. To use this prioritization matrix, all candidate sections are placed in the appropriate category. All pavement sections that fall into category 1 are selected for repair first. Category 2 pavements are selected second, and so on, with a running total of estimated costs being tabulated until the available funds are allocated. Note that this particular matrix displays the manager's preference for repairing primary roads over secondary and secondary over tertiary.

The two prioritization methods described so far are essentially "worst first" scenarios. Although these schemes represent a vast improvement over subjective "ad hoc" selection methods, they have a serious shortcoming in that cost is not considered as

*Prioritization strategies rank categories of pavement sections in descending order of importance. Optimization techniques employ mathematical concepts in which analysis is performed to solve for an optimum solution.

[9]R. E. Smith, M. I. Darter, T. R. Zimmer, and S. H. Carpenter.

[10]D. R. Uzarski and M. I. Darter, "Comparing Different Strategies for Selecting Pavement Sections for Major Repair," paper prepared for presentation and publication at the Annual Meeting of the Transportation Research Board (January 1986).

PCI	RANK		
	PRIMARY	SECONDARY	TERTIARY & PARKING
GOOD 60 56	10	13	X
FAIR 55-41	7	11	X
POOR 40 26	4	8	12
VERY POOR 25 11	2	5	9
FAILED 10 0	1	3	6

Figure 27. Example prioritization matrix.

a decision variable. If cost were considered in the prioritization strategy, an improvement could result by taking advantage of the fact that as PCI drops, repair costs rise. The cost-versus-PCI relationship was displayed in Figure 26 and it will be shown how the curves are developed later in this chapter under the topic of budgeting.

Figure 28 shows a possible prioritization strategy that incorporates cost, at least indirectly. This is known as "reverse prioritization." There is a significant effect on the pavement network if the "reverse prioritization" approach is used instead of the "worst first" approach. This is illustrated in Figure 29 which was the result of a study[10] performed at a military installation. The study assumed a constant and identical funding posture over a 5- to 6-year period in order to gradually upgrade an entire network. By using the reverse prioritization approach, the network is upgraded faster and at less overall cost. This is because emphasis is placed on repairing sections when the cost is relatively low, thus permitting more sections to be repaired each year. Accordingly, new sections that drop below the minimum acceptable PCI are repaired quickly and the remaining funds go toward reducing the backlog until the backlog is eliminated.

If prioritization techniques are to be used, the "reverse prioritization" method is recommended. It should be noted that the calculations in Table 3 result in the "reverse prioritization" curve in Figure 29. While Table 3 represents manual calculations, a spreadsheet software program such as LOTUS could have been used. Further discussion on the calculation process can be found under *Types and Extent of Deterioration* earlier in this chapter and *Justifying Budgets and Repair Projects* later in this chapter.

PCI	RANK		
	PRIMARY	SECONDARY	TERTIARY & PARKING
GOOD 60-56	1	3	
FAIR 55-41	2	5	
POOR 40-26	4	7	10
VERY POOR 25-11	6	9	12
FAILED 10-0	8	11	13

Figure 28. Example reverse prioritization matrix.

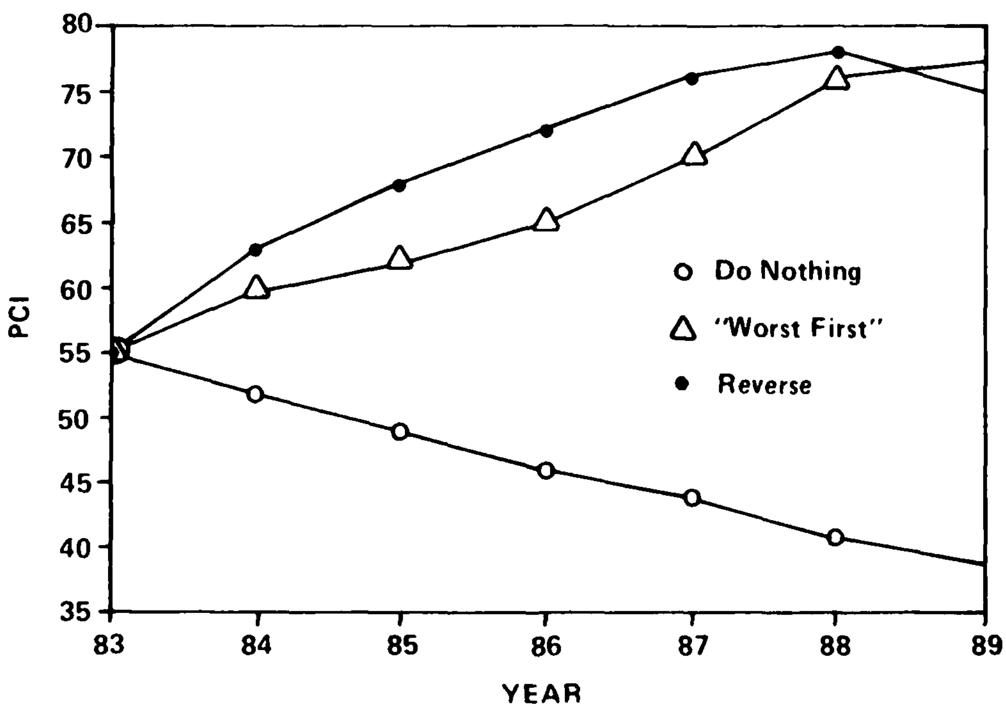


Figure 29. Sample network condition (comparing prioritization methods).

Optimization

Optimization involves maximizing and/or minimizing certain parameters of interest. Two such parameters are cost and benefit. Minimizing cost is always desirable, and maximizing "benefit" would indicate that network performance is at the highest possible level. Two optimization methods are presented that are easy to perform with PAVER. In each case, the optimization strategy will be to combine cost and benefit by maximizing the benefit/cost ratios of the various pavement sections that warrant repair.

The first method is the simplest and can be performed manually or by use of a spreadsheet software program such as LOTUS. Benefit must be calculated for *every* candidate section for major repair by using the BENEFIT report. Benefit is then divided by the unit cost for repairs, giving a calculated benefit/cost ratio for each section. Sections are ranked from the highest to the lowest benefit/cost ratio and then chosen by going down the list and totaling estimated costs until the available funds are allocated. This is done for each desired year in the analysis period, paying particular attention to using projected PCIs and revised benefits and costs as a result of those lower PCIs. Figure 30 gives an example of this method using data from a military installation. However, it should be noted that due to differences in section areas, with the resultant differences in individual section repair costs and budgeting constraints, it may not be possible to select sections in a straight ranking procedure. A given large section with a high ratio may have to be deferred and a smaller section with lower ratios substituted.

The second method uses the Budget Optimization (BUDOPT) report. As in the other optimization method, both repair costs per square yard and benefit must be calculated. These values are then used as input to the BUDOPT program. It should be noted that BUDOPT can accept several repair alternatives per section. For use at the network level where specific alternatives have not yet been formulated, only one alternative will be entered. Figure 31 is an example output. As shown, the output lists sections that should be repaired for a given projected funding level.

For beginning or inexperienced users, prioritization techniques are recommended for use in place of optimization techniques due to the relative ease and low level of understanding needed when using them. Depending on the prioritization method used, results can be very similar to optimization methods.

For the experienced users, optimization techniques are recommended over prioritization techniques. Figure 32 displays the results of comparing both prioritization and optimization techniques at a given funding level to a sample network. The prioritization method given in Figure 27 is compared to the manual optimization method in Figure 30. As another comparison, the reverse prioritization matrix (Figure 28), when compared to the manual optimization method, displays an almost identical effect on the pavement network as a whole (Figure 33); however, *different* pavement sections may be selected for repair in different years.

Benefit

When using optimization techniques, a parameter called "benefit" must be calculated. When used in this context, benefit is a nonmonetary term. It is simply the performance area, or the area under the PCI/time curve. A large performance area is most desirable, since it implies that the pavement is remaining "good" over a period of time, thereby providing the user with a more desirable surface.

Branch Number (BN)	Section Number (SN)	Section Area (SY)	Benefit* (PCI Years)	Unit Cost** ($/SY)	Benefit/ Cost Ratio	Total*** Cost (FY 84 $)
				FY 84		
P1600	01	951	625	11.99	52.13	11402.49
P2023	04	1411	324	6.25	51.84	8818.75
P210B	02	2100	298	5.75	51.83	12075.00
I12AW	#1	287	1167	23.03	50.67	6609.61
I12SQ	01	314	1000	21.87	45.72	6867.18
PW12A	01	236	541	11.99	45.12	2829.04
						48,602.67
				FY 85		
PCONF	02	4371	281	5.40	52.04	23603.40
I14AW	01	322	1000	21.87	45.72	7040.14
II0WA	02	642	792	21.87	36.21	14040.54
						44,684.08
				FY 86		
PO106	02	2347	625	11.99	52.13	28140.53
PE88H	01	795	233	4.55	51.21	3617.25
IR45E	01	399	317	19.15	16.26	7644.00
						39,401.78
				FY 87		
PAR11	02	365	256	5.10	50.20	1861.50
P210B	01	3030	564	11.99	47.04	36329.70
						38,191.20
				FY 88		
P3223	01	2047	264	5.10	51.76	10439.70
PAR11	01	347	264	5.10	51.76	1769.70
IAR11	01	820	1098	23.03	47.68	18884.60
						31,094.00
						201,973.73

*From BENEFIT Report.
**From PCI vs. Cost Curve.
***Assumes $50,000 available annually, with FY 85 and beyond discounted for inflation. (Has same effect as inflating unit costs.)
Note: Sections *not* chosen for repair in given year are not shown.

Figure 30. Example manual optimization method.

INPUT DATA
****

LOC	ALT-NO	EUAC/SY	ANNUAL-BENEFIT	INITIAL-COST
1	1	1.50	22.59	15000.00
2	2	1.35	21.00	12000.00
3	3	1.75	26.40	25000.00
4	4	1.01	15.90	9000.00
5	5	1.25	16.83	18000.00

PROJECTS OF SAME TOTAL COST BUT LESS BENEFIT DELETED
****

LOC	ALT-NO	EUAC/SY	ANNUAL-BENEFIT	INITIAL-COST

NO PROJECT IS DELETED

AN INCREMENTAL BENEFIT-COST ANALYSIS
****

LOC	ALT-NO INC COST	INITIAL-COST INC BENEFIT	EUAL/SY INC BC-RATIO	ANNUAL-BENEFIT AVG BC-RATIO
1	1 1.50	15000.00 22.59	1.50 15.06	22.59 .00
2	2 1.35	12000.00 21.00	1.35 15.56	21.00 .00
3	3 1.75	25000.00 26.40	1.75 15.09	26.40 .00
4	4 1.01	9000.00 15.90	1.01 15.74	15.90 .00
5	5 1.25	18000.00 16.83	1.25 13.46	16.83 .00

PROJECTS DELETED
****

LOC	ALT-NO	INITIAL-COST	EUAC/SY	ANNUAL BENEFIT	INC COST	INC BENEFIT	INC BC-RATIO

SELECTION OF PROJECTS
****

ALT-NO	INITIAL-COST	EUAC/SY	ANNUAL BENEFIT	INC COST	BC-RATIO	CUM COST
4	9000.00	1.01	15.90	1.01	15.74	9000.00
2	12000.00	1.35	21.00	1.35	15.56	21000.00
3	25000.00	1.75	26.40	1.75	15.09	46000.00
1	15000.00	1.50	22.59	1.50	15.06	61000.00
5	18000.00	1.25	16.83	1.25	13.46	79000.00

THE FOLLOWING BEST SOLUTION IS OBTAINED WHEN THE ONE TO ONE AND
PAIRWISE PROJECT REPLACEMENT ARE NOT POSSIBLE.

THE PREFERED SOLUTION OF PROJECTS FOR A FIXED BUDGET OF 40000.00

ALT-NO	EUAC/SY	ANNUAL-BENEFIT	INITIAL-COST
1	1.50	22.59	15000.00
2	1.35	21.00	12000.00
4	1.01	15.90	9000.00

THE TOTAL INITIAL COST IS 36000.00
THE TOTAL ANNUAL BENEFIT IS 59.49
THE EXCESS BUDGET IS 4000.00

$REVERT. *** END BUDOPT PROCEDURE ***

Figure 31. Budget optimization (BUDOPT) report.

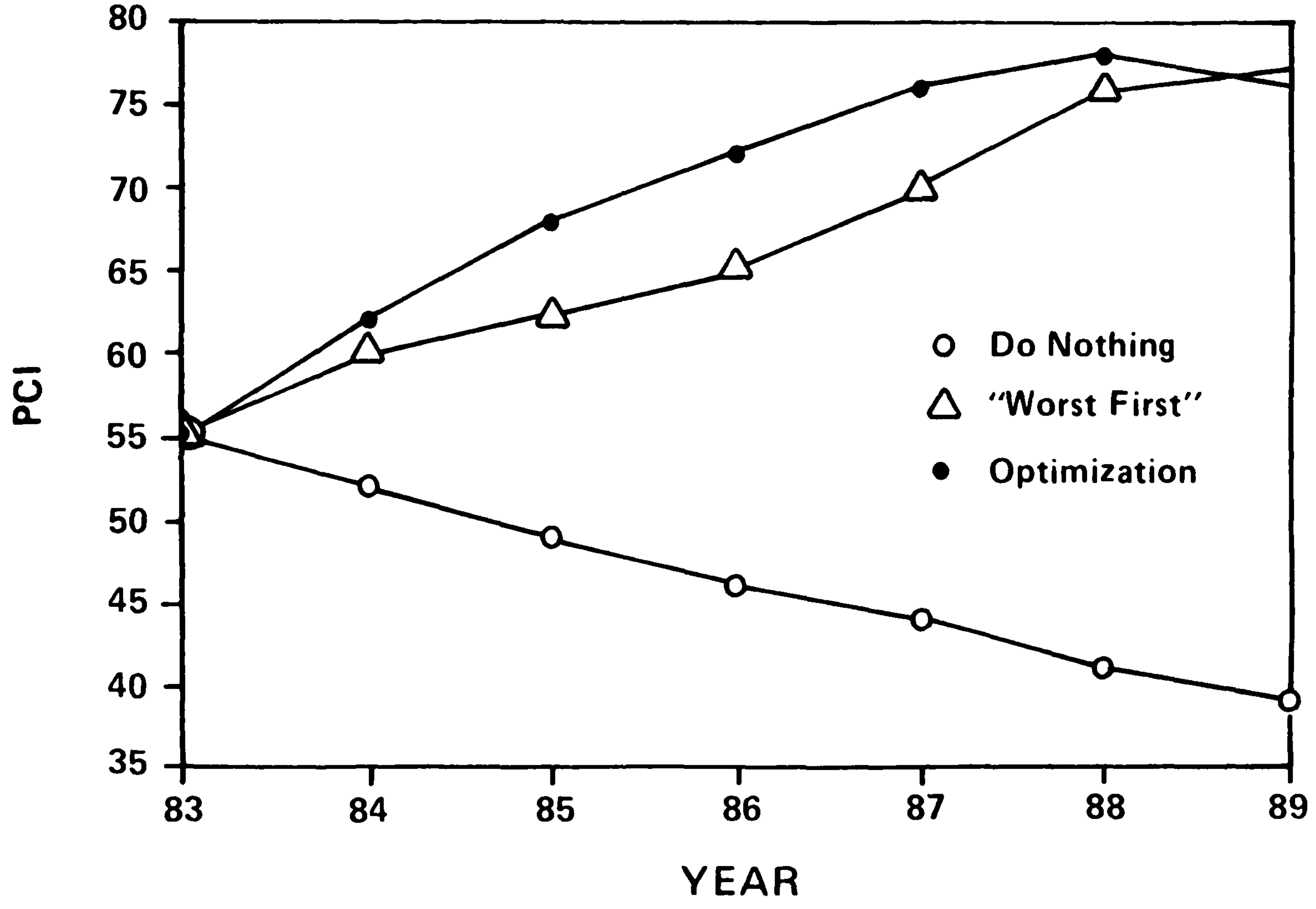


Figure 32. Sample network condition (prioritization versus organization).

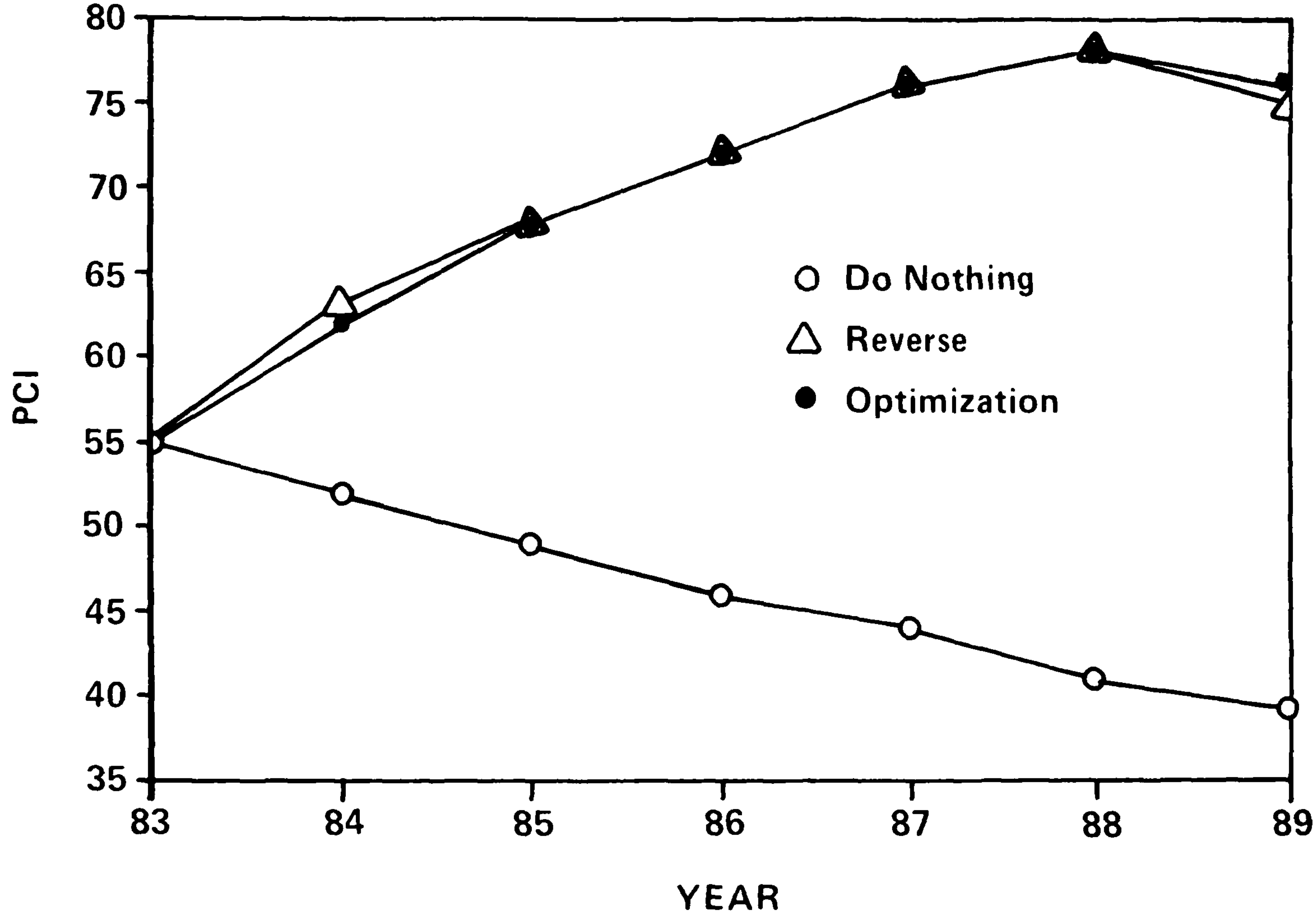


Figure 33. Sample network condition (reverse prioritization versus optimization).

To be an effective management tool, benefit must be adjusted to accommodate the relative importance of one pavement section to the next. Accordingly, a subjective relative weight" factor from zero to one is multiplied by the calculated performance area for different categories of pavement sections. This ensures that more benefit is derived from repairing important pavement sections than those that are least important. Table 5 gives example relative weight factors. If desired, every section can have its own relative weight factor assigned. However, the BENEFIT report will store only six different relative weight factors grouped by pavement type. If more than six are to be used, the appropriate weight factor must be entered for the specific section at the time the report is run. This can be done easily. If more than six factors are to be used and/or they are not grouped by pavement type, it is suggested that the assigned factors be written on the section identification records to keep track of what they are.

Another factor that can be applied is utility. This is also a subjective rating between zero and one and is used to adjust the shape of the PCI/time curve. This rating is applied at different PCI levels for different pavement categories. It is intended to account for the generally accepted philosophy of being more willing to spend money on a pavement section when the PCI is low than when the PCI is high. A study performed on a pavement network at a military installation showed that when the utility values were set to 1.0 at all PCI levels, the maximum positive results on the pavement network occurred. Accordingly, it is recommended that when using the BENEFIT report at the network level to select which pavement sections should be repaired over others, a beginning utility value of 1.0 should be used unless it can be demonstrated through analysis on specific networks that other values should be used.

When running the BENEFIT report, the minimum acceptable PCI is the PCI value below which benefit is not realized. This is, conceptually, a different value from the minimum acceptable PCI used to select candidate sections for repair as discussed earlier. A section may below a minimum acceptable PCI for planning major repair, but still be able to benefit the user or pavement manager. Conversely, the values may be identical. If the user is unsure about what values to use as the minimum acceptable PCIs in the report or if he/she feels that both minimum acceptable PCI values are the same,

Table 5

Example Relative Weight Factors

Section Type	Relative-Weight
Primary Roadway (main gate)	1.00
Primary Roadway	.90
Secondary Roadway	.70
Tertiary Roadway	.60
Primary Parking Lot	.80
Secondary Parking Lot	.50
Primary Runway	1.00
Secondary Runway	.90
Primary Taxiway	.70
Secondary Taxiway	.60
Primary Apron	.80
Secondary Apron	.50

then those PCI values used to select candidate sections for repair can be used (see Table 4). Figure 34 shows an example BENEFIT report. ESL-TR-81-19[11] provides a more detailed discussion of benefit.

The user is cautioned that the terminology in the BENEFIT report was designed for use with airfield pavements. For other pavements, the user must convert to the terminology of the reports. A conversion scheme must be formulated so that, for example, "feature" means "section" and "runway" means "primary roadway," etc.

Practical Use of Prioritization or Optimization Methods

It is not intended that these methods provide the absolute basis for selecting pavement sections. Engineering and management judgment should be used to add or delete pavement sections, as appropriate. However, if engineering and management judgment has been used to properly formulate the prioritization or optimization method, it should be expected that the results would be overridden on an exception basis.

Use of prioritization or optimization methods is only needed once a year. It should be done after the pavements have been inspected for the year and before the development of the annual and long-range work plans. Each section that is currently or is projected to have a PCI below the minimum acceptable in the program year and is not already incorporated into a repair project should be studied.

Developing Maintenance and Repair Plans

Maintenance and Repair Strategy Formulation

The greatest benefit of an effective pavement maintenance management program is the feasibility of sustaining high levels of serviceability at the lowest possible cost. This can be done by establishing effective maintenance and repair strategies. Strategy is an all-encompassing term that can apply to various pavement management components. So far, by establishing a minimum acceptable PCI, a strategy has been established that categorizes sections falling below the minimum acceptable PCI as candidates for major repair and sections that are above the minimum acceptable PCI as candidates for routine or preventive maintenance. Procedures for formulating maintenance and repair target strategies (work types) *within* those broad categories will be discussed here. This is not to be confused with budget strategy formulation, which will be discussed under budgeting.

The strategies will be used to develop annual and long-range work plans; however, it is not intended that the use of such strategies substitute for project-level evaluations, which will be discussed in Chapter 4. These target strategies should be used only for planning.

Major Repair Target Strategies

When sections are repaired, it is very important that the cause of the pavement distress be corrected. Otherwise, a recurrence will rapidly result. Therefore, each section that is a candidate for major repairs should be examined for a generalized target repair strategy based on several different criteria. Sections can first be grouped by

[11] M. Y. Shahin, S. D. Kohn, R. L. Lytton, and E. J. Japel.

```
DATE:=  85/10/10.          BENEFIT ANALYSIS

                          BRANCH NUMBER:= R018

M&R ALTERNATIVE:= MAJOR REPAIR
FEATURE TYPE:= PRIMARY RUNWAY          RELATIVE WEIGHT:= 1.00
PCI:=  PRESENT:=  45    AFTER REPAIR:= 100    MINIMUM:=  60

UTILITY WEIGHTED BENEFIT:=                621.25
RELATIVE UTILITY WEIGHTED BENEFIT:=       621.25
ANNUAL BENEFIT:=                           22.59
               ------------ END OF REPORT ------------
SELECT(A-D):              (H=HELP)
? D
$REVERT. *** END BENEFIT PROCEDURE ***
```

Figure 34. Benefit (BENEFIT) report.

branch use, surface type, and pavement rank. Within those groupings, the condition, type of distress, cause of distress, rate of deterioration, and other indicators, such as curb height remaining, etc., will allow targeting on a proper cost-effective strategy for a given pavement section. To develop such a strategy, a listing of feasible but general work types for a given combination of parameters must be formulated. This list should be as complete as possible, while remaining sensitive to the capabilities of available contractors or in-house forces and available materials. Once the list has been made, a life-cycle cost analysis (see Chapter 4) should be performed on each work type. For planning purposes only, the one with the lowest life-cycle annual cost should be chosen as the most likely target strategy for a section, given certain parameters.

The Evaluation (EVAL) report can be used to help develop the list of work types. This report, which uses the information directly from the section evaluation summary, lists generalized repair alternatives. Figure 35 gives an example of this report. The list of alternatives that this report provides is not intended to be all-inclusive. Engineering judgment must be used to both add and subtract from the list as local conditions dictate. Table 6 shows the list of feasible repair alternatives for the various condition indicators used in the EVAL report.[12]

[12]M. Y. Shahin, S. D. Kohn, R. L. Lytton, and E. J. Japel.

[13]R. E. Smith, M. I. Darter, T. R. Zimmer, and S. H. Carpenter.

```
CURRENT VALUES ARE AS FOLLOWS :=
 1  PCI :=  65
 2  LOCAL VARIATION(Y/N)      := N
 3  SYSTEMATIC VARIATION(Y,N) := N
 4  SHORT TERM RATE OF DETERIORATION(L,N,H):= H
 5  LONG TERM RATE OF DETERIORATION(L,N,H) := H
 6  MAJOR SOURCE OF DISTRESS(LOAD,CLIMATE) := L
 7  LOAD CARRYING DEFICIENCY(Y,N) := Y
 8  SURFACE ROUGHNESS(L,M,H)      := L
 9  SKID/HYDROPLANING PROBLEMS(L,M,H) := L
10  PREVIOUS MAINTENANCE(L,N,H)       := N
SELECT(A-D) :=
? C

DATE := 28 MAR 85          FEASIBLE M&R ALTERNATIVES

BASE := CAMERON STATION              FEATID := IBSTC-   PCI:=  65
FEATNM := B STREET                   M&R REPAIR ZONE := ROUTINE-MAJOR-OVERALL

          ***** RECOMMENDED MAINTENANCE ALTERNATIVES *****

           1 :=  RECONSTRUCTION
           2 :=  OVERLAY STRUCTURAL AC
           4 :=  OVERLAY PCC
          11 :=  RECYCLE STRUCTURE
          13 :=  DRAINAGE MODIFICATION

          *** END ***
```

Figure 35. Evaluation (EVAL) report.

Table 6

Feasible Repair Alternatives in EVAL Report

Alternative Number	Description
1	Reconstruction
2	Structural overlay (asphalt-concrete)
3	Leveling overlay (asphalt-overlay) -- 2-in. nominal
4	PCC overlay
5	Grooving
6	Grinding
7	Porous friction surface
8	Surface treatment
9	Slab jacking
10	Surface recycling
11	Structure recycling
12	Redefine feature
13	Drainage modification
14	Routine maintenance

Another method would be to use the decision tree concept. Figure 36, which is just one of a series of decision trees developed for a specific military installation,[13] was prepared based on engineering judgment and knowledge of contractors' capabilities within the geographic area of the installation. As shown by the decision criteria, many feasible work types are identified. The numbers on the chart illustrate the average annual unit cost and the construction unit cost. The alternative with the lowest average annual cost is selected as the most appropriate strategy for that pavement section; the estimated construction cost will be used later in the budgetary and project planning process.

As construction technologies and contractor capabilities change, the list of feasible alternatives must be upgraded. The costs associated with the alternatives should be updated annually.

Preventive Maintenance Strategies

Preventive maintenance consists of activities intended to slow the deterioration rate in an effort to preserve the pavement investment. Accomplishing these activities may or may not immediately increase the PCI. The two most common preventive maintenance activities to the pavement itself are seal coating and crack sealing of asphalt pavements and joint sealing of concrete pavements. Other preventive maintenance activities would include such items as cleaning drainage structures, etc. Accomplishing these activities at the right time can greatly increase pavement life.

Preventive maintenance activities are triggered based on time and condition. Newly constructed or recently repaired sections should be scheduled for preventive maintenance activities to the pavement every 3 to 5 years and drainage structures should be cleaned annually, depending on local conditions. To implement such a strategy for preventive maintenance, it is easiest to automatically schedule sections for that work on a recurring schedule. If the pavement inspections show that the section is deteriorating more than expected, the practicality of continuing with the preventive maintenance should be evaluated, and the section should perhaps be scheduled for major repair. For example, a section constructed with asphalt and having received one seal coat is scheduled for a second seal coat. Routine inspection indicates that the section is showing a substantial increase in structural distress, and is therefore structurally deficient to carry the given load. In this case, it may be inappropriate to spend the money on the seal coat, since it will do little to slow the structural decay other than retard water infiltration, which may be accelerating the decay. If the section has dropped below the minimum acceptable PCI, it will become a candidate for major repairs. If the section is still above the minimum acceptable PCI, it may require routine maintenance, either in conjunction with or instead of, the preventive maintenance. This work will be incorporated in the annual and long-range work plans.

Routine Maintenance Strategies

Routine maintenance refers to the activities required to correct pavement distress locally. These are generally minor problems, and the section PCI will normally be above the minimum acceptable. Examples of these activities are spall repair, small patches, and patch replacement. Routine maintenance should be a planned strategy done after the section inspection. The inspection results for those sections will be used to formulate part of the annual work plan, which is the implementation portion of the strategy.

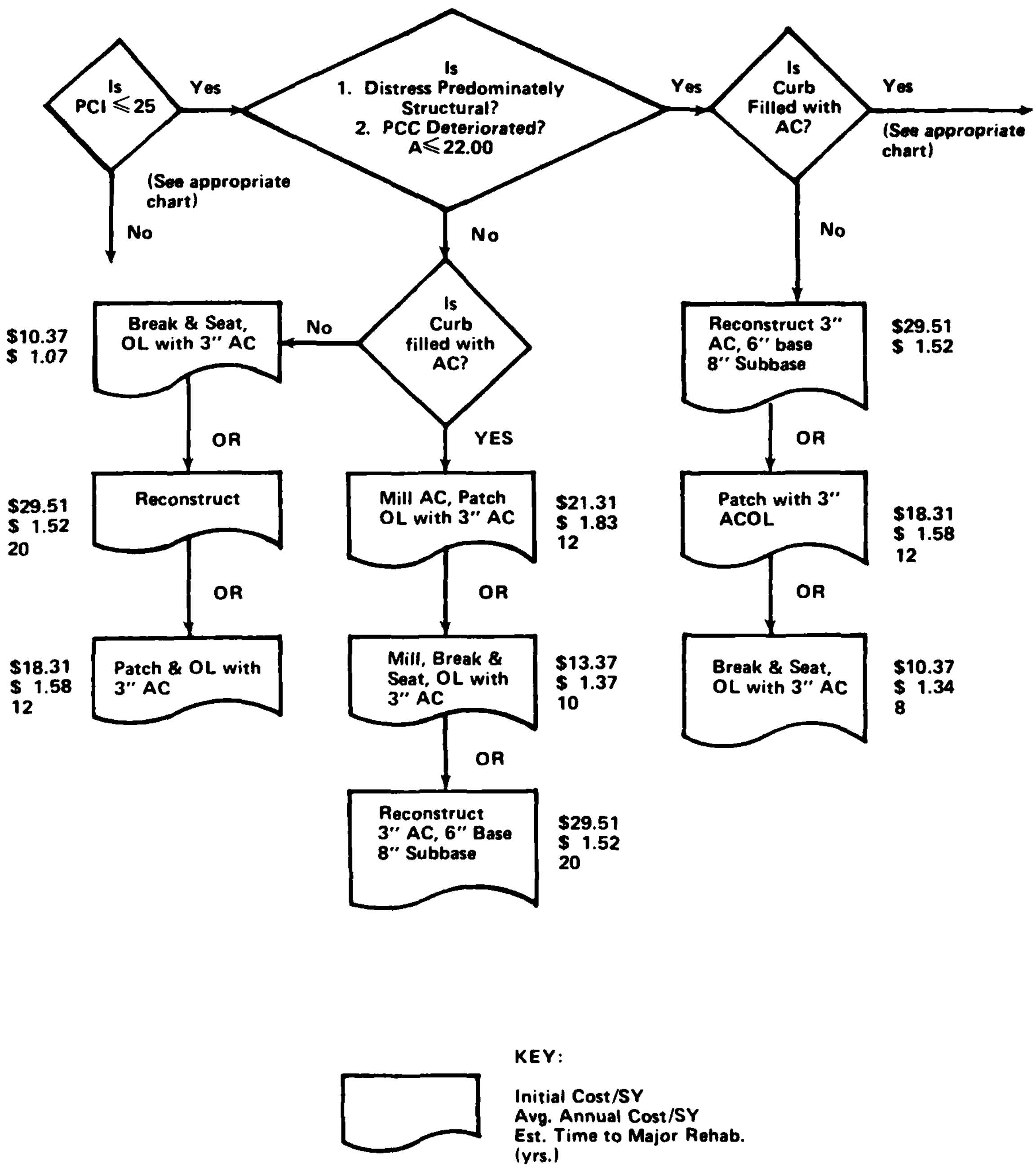


Figure 36. Example target strategies decision tree.

The strategy formulation consists of deciding the appropriate correction for the pavement distresses. These are choices of the user and are stored in PAVER as the maintenance policy. Figure 37 shows an example Maintenance Policy (POLICY) report.

Localized Repair Strategies

This repair strategy includes emergency repairs or scheduled repair work needed for safety. This would apply to sections below the minimum PCI that are awaiting repair, yet have conditions that warrant maintenance. Most typical would be pothole filling. When a pavement has reached a point of severe structural decay, potholes may form quickly. Even though a major repair project may be planned, the time needed to plan and carry out the repair project may leave the pavement in an unsafe condition for some time. A strategy of temporary repairs may be needed to keep the pavement relatively safe for the traveling public. These activities can be identified through the scheduled inspection or from windshield* tours around the installation.

Specific repair strategies for correcting distresses are the choice of the user and are to be selected and stored in the database. They will be displayed in the POLICY report.

The budgeting for the repair, preventive maintenance, routine maintenance, and local repair strategies will be discussed later in this chapter.

Combining Sections Into Logical Maintenance and Repair Projects

Specific projects must be developed for completing the work. Each maintenance or repair project will probably involve several sections. Therefore, there must be a logical grouping based on a number of factors, including:

1. Manner of accomplishment
   a. In-house
   b. Contract

2. Work classification
   a. New construction
   b. Repair
   c. Maintenance

3. Work type (target strategy)

4. Length of the construction season

5. Geographic location

6. Pavement function and traffic

7. Amount of work that can be done for the amount of money budgeted.

Figure 38 shows this decision process. The primary task is to put together projects of similar or the same work type that can be done in the required time in the same

*Windshield tours are conducted by driving around the installation and observing the pavement condition from the vehicle.

REPORT DATE- 04/15/85

MAINTENANCE POLICY

DISTRESS TYPE	SEV	REPAIR TYPE	MTL CODE	REPAIR UNIT	LABOR HR/UNIT	********UNIT COSTS($)******** LABOR	MTL	EQUIP	TOTAL
ALLIGATOR CR									
	H	DEEP PATCH	120	SF		.860	.860		1.720
	L	SEAL COATING	156	SY		.270	.270		.540
	M	SHALLOW PATCH	120	SY		6.080	5.400		11.480
BLEEDING									
	H	SPREAD SAND/AGG	151	SY		.540	.720		1.260
	M	SPREAD SAND/AGG	151	SY		.540	.720		1.260
BLOCK CR									
	H	CRACK FILLING	170	LF		.900	.900		1.800
	L	SEAL COATING	156	SY		.270	.270		.540
	M	CRACK FILLING	170	LF		.900	.900		1.800
BUMPS/SAGS									
	H	SHALLOW PATCH	120	SY		6.080	5.400		11.480
	M	SHALLOW PATCH	120	SY		6.080	5.400		11.480
CORRUGATION									
	H	SHALLOW PATCH	120	SY		6.080	5.400		11.480
	M	SHALLOW PATCH	120	SY		6.080	5.400		11.480
DEPRESSION									
	H	SHALLOW PATCH	120	SY		6.080	5.400		11.480
	M	SHALLOW PATCH	120	SY		6.080	5.400		11.480
EDGE CR									
	M	SHALLOW PATCH	120	LF		1.190	.250		1.440
	H	SHALLOW PATCH	120	LF		1.190	.250		1.440
JT SEAL DAMAGE									
	H	CRACK FILLING	170	LF		.900	.900		1.800
	M	CRACK FILLING	170	LF		.900	.900		1.800
LANE/SHLDR DROP									
	H	DRAINAGE CORREC	311	LF		.970	1.620		2.590
	M	DRAINAGE CORREC	311	LF		.970	1.620		2.590
LONG/TRANS CR									
	H	CRACK FILLING	170	LF		.900	.900		1.800
	L	CRACK FILLING	170	LF		.900	.900		1.800
	M	CRACK FILLING	170	LF		.900	.900		1.800
PATCH/UTIL CUT									
	H	DEEP PATCH	120	SF		.860	.860		1.720
	M	SHALLOW PATCH	120	SY		6.080	5.400		11.480

Figure 37. Maintenance policy (POLICY) report.

```
POLISHED AGG
            N SPREAD SAND/AGG  151 SY            .540    .720          1.260

POTHOLE
            M SHALLOW PATCH    120 SY           6.080   5.400         11.480
            L SHALLOW PATCH    120 SY           6.080   5.400         11.480
            H DEEP PATCH       120 SF            .860    .860          1.720

RUTTING
            M SHALLOW PATCH    120 SY           6.080   5.400         11.480
            H DEEP PATCH       120 SF            .860    .860          1.720

SHOVING
            M SHALLOW PATCH    120 SY           6.080   5.400         11.480
            H DEEP PATCH       120 SF            .860    .860          1.720

SLIPPAGE CR
            H DEEP PATCH       120 SF            .860    .860          1.720
            M SHALLOW PATCH    120 SY           6.080   5.400         11.480

WEATHER/RAVEL
            H SPREAD SAND/AGG  151 SY            .540    .720          1.260
            M SPREAD SAND/AGG  151 SY            .540    .720          1.260

$REVERT. *** END POLICY PROCEDURE ***
/
```

Figure 37 (Cont'd).

geographic area and completed for the budgeted amount. This type of project combination will help reduce the total cost of the project by allowing a contractor to perform larger quantities of similar work in a smaller geographic area.

Once projects are developed, specific information about the projects can be stored in the PAVER database. The Work Requirement (WORKREQ) or Record (RECORD) reports (Figures 39 and 40, respectively) are used to retrieve project information.

Multi-Year Plan Development for Major Repair Projects

Major repair project planning must encompass several years. The projects must be planned for a program year, and that can be anywhere from one to possibly five or six years in the future.

For major repair projects, all sections projected to be below their minimum acceptable PCI in the program year should be planned for accomplishment, or, if there are limited funds, sections should be prioritized or optimized for repair. Either way, a program year could have a number of sections identified for repair. When a target strategy is applied to each section, it may be found that many different repair strategies may be appropriate for the various sections needing repair. Likewise, the various sections that need repair may be scattered around the installation, or adjacent sections may need repair in consecutive years.

To develop repair projects properly, the user must look beyond the program year for one or two years and apply the same analysis used for sections actually needing repair in the program year. This will result in a larger number of sections to study for combining into logical projects. Station maps should be used to display sections needing

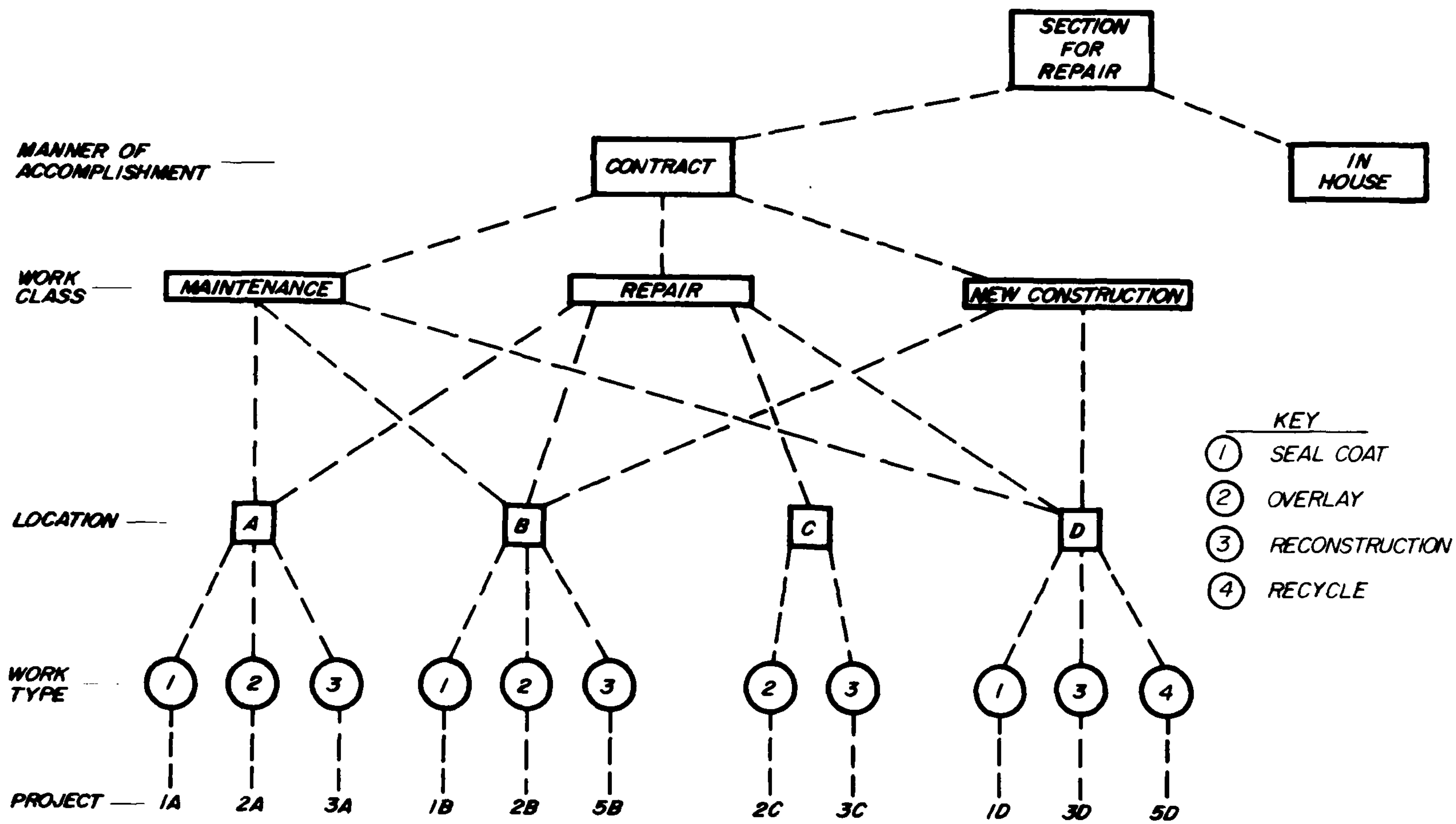


Figure 38. Project development decision process concept.

REPORT DATE-08/11/85 WORK REQUIREMENTS

AGENCY NUMBER = 210 GREAT LAKES NTC

SECTION CATEGORY TYPE N PAVEMENTS
WORK TO BE DONE

WORK PROPOSED- 10101 REPROCESSING - ALLIGATOR CR (1.00 IN. THICK)
MATERIAL=AC

BRANCH IDENTIFICATION	SEC NO	LABOR HOURS	LABOR COST$	MAT'L COST$	EQUIP COST$	WORK QUAN SY	TOTAL COST$	PRIOR -ITY	REC FY	FIN-ANCED
BRANCH # IDSTR										
D STREET										
	01					2685.00	11868		86	
*OL W 1 INCH AC REPROCESSING										

TOTAL						2685.00	11868			

****
GRAND TOTAL $11868
(SECTION CATEGORY TYPE N)

REPORT DATE-08/11/85 WORK REQUIREMENTS

AGENCY NUMBER = 210 GREAT LAKES NTC

SECTION CATEGORY TYPE N PAVEMENTS
WORK TO BE DONE IN HOUSE

WORK PROPOSED- 11110 SEAL COATING - LONG/TRANS CR
MATERIAL=SING-LAYER AGG SEAL

BRANCH IDENTIFICATION	SEC NO	LABOR HOURS	LABOR COST$	MAT'L COST$	EQUIP COST$	WORK QUAN SY	TOTAL COST$	PRIOR -ITY	REC FY	FIN-ANCED
BRANCH # IDSTR										
D STREET										
	01					2363.00	18431		87	NO
*PATCH & SEAL										

TOTAL						2363.00	18431			

****
GRAND TOTAL $18431
(SECTION CATEGORY TYPE N IN HOUSE)

Figure 39. Work requirements (WORKREQ) report.

AGENCY NUMBER = 210 GREAT LAKES NTC

----- WORK REQUIRED SECTION 01 - D STREET

DATE REPORTED	WORK DESCRIPTION	THICKNESS (IN)	WORK QUANTITY	EST COST($)	PRIOR-ITY	REC FY
09/30/82	REPROCESSING	1.00	2685.00 SY	11868		86
*OL W 1 INCH AC REPROCESSING						
08/30/83	SEAL COATING		2363.00 SY	18431		87
*PATCH & SEAL						

Figure 40. Record (RECORD-REQUIRE) report.

repair and the appropriate work type. Patterns that begin to develop on the map can be used to group sections into logical projects.

An example illustrating the effect of geographics would be three consecutive sections of a given pavement branch, all planned for a similar target strategy. However, based on the PCI projections, sections 01 and 03 should be repaired in FY88, but section 02 should be repaired in FY89. In this case, it would be most logical to combine all three sections into one project in either FY88 or 89, depending on funding availability. This would provide the greatest construction cost economy.

Work type (target strategy) must be reviewed for each section when a project is developed. This is because construction economy will be lost if too many different strategies are combined on one project. Different kinds of work may require different equipment, skills, and materials. If these differ greatly on a given project, the effects will be reflected in higher bid prices. An example would again be three consecutive sections in a given pavement branch. Two sections require structural improvement, which can be done through a relatively thick overlay. The third section, which only has environmental distress, can have a target strategy of surface recycling. In this case, it would be impractical for a contractor to bring in the equipment required to do surface recycling for just one section. Therefore, consideration should be given to changing the strategy for that section to conform to an overlay in order to match the repair strategy of the other sections. The overlay need not be as thick as the others, but since it will involve the same equipment, it may be the most economical and practical repair under those circumstances.

This is not to say that when developing repair projects all of the sections within a given project must have the same kind of repair. Rather, the engineer must remain sensitive to the differences in construction skills, equipment requirements, and materials availability when planning projects. Proper engineering judgment must be used at all times when these projects are being developed.

The user is again reminded that this long-range repair plan is o be used for planning purposes only. Each section will still require a detailed project-level evaluation before the most feasible repair alternative is selected for design. It may not be the same alternative formulated in the network-level plans.

Revising Existing Major Repair Plans

Any time new projects are developed, they must be compared to existing projects that will be in the various stages of execution: project evaluation, design, and construction. The purpose of the comparison is to determine whether individual pavement sections should be "traded" between projects if there is time during the planning process. The trading would be done within budgetary constraints and only if a more logical work plan would result in terms of timing, work type, and geographic considerations. This ensures that the planning process remains dynamic and that effective engineering and management judgment is exercised in getting sections properly repaired at the right time at the most reasonable cost.

Preventive Maintenance Planning

As was previously discussed, work of this type should be scheduled based on time from construction, last major repair, or time from last preventive maintenance treatment. The cyclic nature of this work makes it easy to plan and program. Also, this type of work will not require a project-level evaluation. Cost and quantities can be estimated by using the Maintenance and Repair Guidelines (MRG) report.

Figure 41 shows an example MRG report for an asphalt pavement. By knowing the unit cost per square yard for a surface treatment, the overlay option feature of the MRG report can be used to estimate the quantities and cost for a seal coat. When using the MRG report in this way, the user needs to respond with a "Yes" when the prompt for overlay is asked. Treat the 1-in. overlay as a seal coat and enter the unit cost. The report will provide quantities and cost on a section-by-section basis.

Figure 42 shows an example MRG report for joint-seal of PCC pavement. In this case, the MRG report is even easier to use. Joint seal damage will have been identified from the pavement inspection. The unit cost for repair will already have been identified in the maintenance policy. The MRG report will automatically combine the two, giving quantities and cost for repair on a section-by-section basis. When using the MRG reports in this way, it is not necesary to run the report for all distresses present. The user has the option of running the report for selected distresses present or for all distresses present.

Routine Maintenance Planning

Routine maintenance planning is easily done at the network level. From the results of the annual pavement inspection, the MRG report will match distresses and unit costs from the maintenance policy and estimate cost and quantities. The best practice would be to do the work either in the current year or the next year. Unless the deterioration rate is high and there is systematic or localized variation in the distress, this work will apply to sections above the minimum acceptable PCI; therefore, a project-level evaluation may not be necessary. However, if something unusual is occurring to the section, or if a detailed analysis is desired, a project-level evaluation will be required. In any case, when planning maintenance, the distress types, quantities, and severities should be considered carefully. Maintenance is not a substitute for major repairs, but it can have a profound effect on lengthening the period between major repairs for given pavement sections. Deferring maintenance will only reduce the interval between major repairs.

The results of the MRG reports should be used to plan for and estimate the personnel needed and prepare their job orders or contracts, as appropriate.

REPORT DATE - 85/03/28.

MAINTENANCE AND REPAIR GUIDELINES

BRANCH NAME - B ST
BRANCH NMBR - IBSTR
SECTION NMBR - 04

SECTION LENGTH - ****** LF
SECTION WIDTH - **** LF
SECTION AREA - 656 SY

INSPECTION DATE - 11/15/83

SECTION PCI - 81

DISTRESS TYPE	DIS SEV	DIST-QTY WORK-QTY	WORK TYPE	MATL CODE	LABOR HOURS	LABOR COST$	MAT'L COST$	EQUIP COST$	TOTAL COST$
PATCH/UTIL CUT	L	473 SF							
			--- NO MAINTENANCE POLICY AVAILABLE ---						
SLIPPAGE CR	H	8 SF							
		0 SY	SHALLOW PATCH	120	0.0	0	0	0	4
			OVERLAY	151					743
				TOTAL	0.0	0	0	0	747

Figure 41. Maintenance and repair guidelines (MRG) report for AC pavement section.

BRANCH NAME - NIMITZ AVENUE
BRANCH NUMBER - INIMI
SECTION NMBR - 01

SLAB LENGTH - 20.0 LF
SLAB WIDTH - 11.0 LF
NMBR OF SLABS - 96

INSPECTION DATE - 08/10/83

SECTION PCI - 50

DISTRESS TYPE	DIS SEV	DIST-QTY WORK-QTY	WORK TYPE	MATL CODE	LABOR HOURS	LABOR COST$	MAT'L COST$	EQUIP COST$	TOTAL COST$
JT SEAL DAMAGE	H	96 SLAB							
		3936 LF	JOINT FILLING	171	0.0	1771	3503	787	6061
				TOTAL	0.0	1771	3503	787	6061

Figure 42. Maintenance and repair guidelines (MRG) report for PCC pavement section.

Localized Repair Planning

Localized repairs are generally unplanned maintenance activities required to maintain the pavement's integrity or safety. Routine inspections or windshield tours will identify these deficiencies. Actual repair work should be conducted in groups without regard for sections so that it can be done quickly (i.e., doing all potholes at the same time). Project-level evaluations are not necessary, and there is seldom a need for detailed quantities of repair items. This work should be done as soon as possible.

Preparing a Budget

An essential annual management activity is the preparation of the maintenance and repair budget. This task generally covers a 3-year period beginning with the next year, and is frequently filled with uncertainty about the true maintenance and repair budgeting needs. With PAVER, the process is simplified and rational budgets can be prepared for long-range repair projects, preventive maintenance, routine maintenance, and localized repair.

Long-Range Repair Budget

The Budget Planning (BUDPLAN) report can be used to prepare long-range repair budgets. This report will prepare a budget for each of the next 5 years, beginning with the current year, and will reflect the network's true needs. Similar to the FREQ report, BUDPLAN will use a PCI projection to ascertain when an individual section will drop below the minimum acceptable PCI. For that year, BUDPLAN will multiply the section area by the unit cost for repair on a square yard basis for a given projected PCI value; it will then compute the cost to repair that section. The report will summarize all sections requiring repair in that year and provide a total budget. This report can be used to prepare budgets for different combinations of branch use, pavement rank, and surface type.

Two of the required input elements needed to run the report are minimum PCI for the given branch use/pavement rank combination and the unit cost for repair of the given surface type for the mid-PCI of five different PCI ranges. The minimum PCIs to be used are those that have been established previously as the minimum acceptable PCI. The PCI-versus-cost relationship will be discussed in the following section. Figure 43 displays the BUDPLAN report.

If there is a large backlog of repairs at the installation, the BUDPLAN report will display a very large budget requirement in the first year. Often, this amount is too high, and must be spread out over several years. In a practical sense, the procedure used for preparing projects over several years has already been discussed under the *Prioritization and Optimization* and the *Developing Maintenance and Repair Plans* sections. The BUDPLAN report can also be modified to defer repair projects by modifying the minimum acceptable PCIs for the report. To do this, the first year would have to display a low minimum PCI; each year thereafter, the minimum PCI would be raised, thereby leading to a gradual improvement in the pavement network. If this feature is used, the user should note that the report will budget for repairs on a "worst-first" basis. If the installation will be using a "worst-first" prioritization strategy, with the sections actually being repaired as per the BUDPLAN, the BUDPLAN report will provide reasonable results. If a different prioritization or optimization method is used, the BUDPLAN report will estimate budgets that will generally not match the planned strategy.

```
                      BUDGET PLANNING REPORT
AGENCY NAME: VINT HILL FARMS STATION     REPORT DATE:  85/10/08.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S
SURFACE TYPE: AC
ZONE          : VHST
INFLATION RATE:    4.50
SECTION CATEGORY: A B C D E F G I J K Y N
                        TABLE OF BUDGET PLANNING
```

FY TO REPAIR	PRIMARY	SECONDARY	TERTIARY	OTHER	N-APPLIC	TOTAL COST($1000'S)
		PAVEMENT RANK				
1986	62.63	31.51	0.00	0.00	0.00	94.14
1987	0.00	11.59	0.00	0.00	0.00	11.59
1988	24.29	20.41	0.00	0.00	0.00	44.70
1989	12.22	39.88	0.00	0.00	0.00	52.10
1990	31.03	0.00	0.00	0.00	0.00	31.03
1991	69.53	0.00	0.00	0.00	0.00	69.53

```
   TOTAL NO. OF SECTION:       15
   SECT. NOT NEEDING REPAIR:     5
   NO. OF MISSING VALUE:        0
```

```
                      BUDGET PLANNING REPORT
AGENCY NAME: VINT HILL FARMS STATION     REPORT DATE:  85/10/08.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S
SURFACE TYPE: AC
ZONE          : VHST
INFLATION RATE:    4.50
SECTION CATEGORY: A B C D E F G I J K Y N


   COST    FY TO
           REPAIR
                 !
                 !
   94.14   1986  !**********************************************************
                 !
                 !
   11.59   1987  !*******
                 !
                 !
   44.70   1988  !***************************
                 !
                 !
   52.10   1989  !********************************
                 !
                 !
   31.03   1990  !*******************
                 !
                 !
   69.53   1991  !*******************************************
                 !
                 !
 --------        !--------------!--------------!--------------!--------------!
  303.10         0             24             48             72             96

                                     COST IN THOUSANDS


   TOTAL NO. OF SECTION:       15
   SECT. NOT NEEDING REPAIR:     5
   NO. OF MISSING VALUE:        0
```

Figure 43. Budget planning (BUDPLAN) report.

BUDGET PLANNING REPORT
AGENCY NAME: VINT HILL FARMS STATION   REPORT DATE: 85/10/08.

BRANCH USE: ROADWAY
PAVEMENT RANK: P S
SURFACE TYPE: AC
ZONE : VHST
INFLATION RATE: 4.50
SECTION CATEGORY: A B C D E F G I J K Y N

LIST OF CASES IN
BUD PLANNING REPORT

FY TO REPAIR	BRANCH NUMBER	BRANCH USE	SECT. NO.	PAVE. RANK	SUT	PRO PCI	$/SY	SEC AREA	COST ($1000'S
1986	IVBIC	ROADWAY	02	S	AC	65	8.10	1760	14.25
1986	IVBIC	ROADWAY	03	S	AC	70	6.41	733	4.70
1986	IVPOP	ROADWAY	01	S	AC	67	7.42	1692	12.56
1986	IVROU	ROADWAY	02	P	AC	59	10.12	6187	62.63
1987	IVBIC	ROADWAY	04	S	AC	68	7.09	1566	11.59
1988	IVBEA	ROADWAY	03	S	AC	70	6.41	2359	16.51
1988	IVBIC	ROADWAY	05	S	AC	70	6.41	557	3.90
1988	IVBIC	ROADWAY	08	P	AC	68	7.09	1517	11.74
1988	IVHAR	ROADWAY	02	P	AC	69	6.75	1704	12.56
1989	IVBIC	ROADWAY	09	P	AC	68	7.09	1511	12.22
1989	IVHAR	ROADWAY	01	S	AC	70	6.41	3410	24.94
1989	IVHAR	ROADWAY	04	S	AC	69	6.75	1940	14.94
1990	IVHEL	ROADWAY	02	P	AC	70	6.41	4060	31.03
1991	IVBIC	ROADWAY	07	P	AC	70	6.41	2760	22.05
1991	IVHAR	ROADWAY	03	P	AC	68	7.09	5378	47.48

TOTAL NO. OF SECTION: 15
SECT. NOT NEEDING REPAIR: 5
NO. OF MISSING VALUE: 0

MINIMUM PCI TABLE

	P	S
ROADWAY	70	70
	70	70
	70	70
	70	70
	70	70
	70	70

SUT UNIT COST TABLE

SUT	$ COST/SQYD				
	PCI 0-20	21-40	41-60	61-80	81-100
AC	29.29	28.15	13.16	6.41	1.54

Figure 43 (Cont'd).

This is not to say that the BUDPLAN report cannot be used if the prioritization or optimization scheme is not a "worst-first." By running the report with the previously established minimum acceptable PCIs, the user will still obtain an accurate summary of the true repair backlog for the entire network for both the present and for 5 years in the future.

Although the BUDPLAN report will give a cost of repair on a section-by-section basis as well as for the network as a whole, the user is advised not to use this report on a section-by-section basis. The user is reminded that the cost/sq yd figure used in the report is for *average* value only. Actual section repair needs can vary greatly from the average. Thus, when the average figures are used on a section-by-section basis, considerable error could result. It is recommended that the BUDPLAN report be used to reflect total network or subnetwork needs by zone or section category.

If a large first-year backlog cannot be funded, the budgets can be prepared easily by simply adding up the repair costs per section for the year in which they have been programmed for repair according to the long-range repair plan. This is a practical consideration in that maintenance and repair planning is often driven by monetary ceilings placed on the expected available funds. In essence, actual budgeted dollars usually fall short of the needed dollars. BUDPLAN will provide an estimate of the needed dollars, and once the expected available dollars are estimated, the planned repair program can be tailored to fit the program. It is this type of realistic scenario that has led to the concept of prioritizing or optimizing projects for repair.

PCI-Versus-Cost Relationship for Major Repairs

The PCI-versus-cost relationship is an inverse function. The cost of repair increases in a curvilinear fashion as the PCI decreases. This relationship will hold until the PCI reaches a point at which the only feasible economical alternative is to reconstruct the pavement section. At and below that PCI value, the cost will remain constant (see Figure 26).

To use the BUDPLAN report and do the project planning, a cost-versus-PCI relationship must be developed. Ideally, there will be different curves for each branch use, pavement rank, and surface type combination. Each curve is developed by using the results of the target strategies developed for major repairs. Target strategies apply to different PCI ranges, so the unit cost per square yard for repairs must be estimated. This should be done for several sections within each branch use, pavement rank, and surface type combination. Matching the cost per square yard for repair to the section's PCI value enables the curves to be plotted. If there is little differentiation between the cost-versus-PCI relationship among the groupings of branch use, pavement rank, and surface type, they can be combined as appropriate onto fewer curves.

It should be noted that when running the BUDPLAN report, the program will assume that the cost-versus-PCI relationship for a given branch use and surface type is the same for all pavement ranks. If the same branch use and surface type combinations have different cost-versus-PCI curves for the different pavement ranks, the BUDPLAN report will have to be run separately for each combination. The total repair budget will then have to be prepared by adding the results of the individual BUDPLAN reports.

PCI-Versus-Cost Relationship for Routine Maintenance

PCI-versus-cost curves for this category of work need be developed only for the different combinations of branch use and surface type. The data to prepare these curves will come from the MRG reports. A sampling of pavement sections ranging from the minimum acceptable PCI to 99 must be selected for the given branch use and surface type combination, since this is the range of PCIs for which routine maintenance should be applied. MRG reports must be run for the selected sections. The results of those reports must be converted to cost per square yard and again matched to the section's PCI value. The results are plotted on a graph as for major repairs. It is recommended that this PCI-versus-cost relationship not include data for cyclic preventive maintenance. That budget will be computed separately.

Routine Maintenance Budget

The routine maintenance budget can also be prepared by using the BUDPLAN report. It is run in the same way as the long-range repair budget; however, in this case, the minimum PCI must be taken as 99. The results from the BUDPLAN report for the total first-year major repair budget are subtracted from the total BUDPLAN report results. The difference will be the required routine maintenance budget for the current year.

It is also possible to estimate routine budgets for the current year by summing the results of individual section MRG reports. However, this can be very tedious when many sections are above the minimum acceptable PCI.

It can be difficult to estimate accurate routine maintenance requirements for later years. Some sections will drop below the minimum acceptable PCI, other sections will be

in various stages of planning for repair, some maintenance work will have been deferred from previous years, sections will continue to deteriorate, unit costs will change, etc. Accordingly, it is easiest to use the current-year budget and add a contingency for later years unless a major repair program will greatly alter the network PCI.

Preventive Maintenance Budget

The BUDPLAN report will not be used to budget for preventive maintenance. The funds budgeted for this work will be determined by summing the preventive maintenance costs for the individual sections that require preventive maintenance in the given years.

Localized Repair Budget

Localized repair is emergency work to keep pavement sections in a safe condition until major repairs can be made. These are pavement sections with PCIs below the minimum acceptable value. The PCI-versus-cost relationships developed thus far do not include data for pavement sections in this category. The nature of this work makes it very difficult to project and budget for. The simplest way would be to estimate the need based on historical data or to add a contingency factor in the routine maintenance budget. This can be done by adding a certain percentage to the unit costs used to develop the cost-versus-PCI relationship. The appropriate percentage will be dictated by local conditions.

Justifying Budgets and Repair Projects

One of the most important management functions that PAVER can assist with is justifying budgets and repair projects. It does this by showing network conditions before and after budget execution and project completion.

The FREQ report is the primary report used in this analysis. It provides normalized current condition information and predicts network conditions if no major repair projects are done. The Analysis of Local Repairs (ANALOC) and Consequences of Local Repair (CONLOC) reports will also sometimes be used. Since these two reports are used extensively in project-level evaluation, their use will be discussed in detail in Chapter 4.

Network Condition Versus Budget

To analyze the effects of a specific budget or repair project, the network condition after completion must be compared with the network that would result if the project is not done or the budget not executed. This latter condition constitutes the "do-nothing" alternative. "Do-nothing" conditions (maintaining current practices short of major repair) can be obtained directly from the FREQ report for each year in the analysis period. The overall effects on the network if the project is accomplished must be analyzed manually. To do that, the user must first know what the PCIs of the individual pavement sections will be after maintenance or repair in the year when the repair is completed. Sections that are reconstructed or otherwise repaired with a new surface course will have an assumed PCI of 100 in the year of repair. Sections that have received maintenance or localized repair may or may not have an increase in PCI, depending on the nature of the work performed. PCI after repair can be found in the ANALOC report. The overall network PCI can then be obtained by manually averaging PCIs of the sections that have not received repair with those that have received repair or maintenance. The averaging can be done on a PCI-per-section basis or on a PCI-per-square-yard basis (see the section on *Type and Extent of Deterioration*). The identical

analysis would be performed in each year of the analysis period to determine what the overall network PCI would be if repairs were made.

Another factor needed to estimate network PCIs is a determination of what PCIs will be for individual sections at a future time after the repair has been performed. For major projects, where the PCI has gone to 100 after the repair, a deterioration rate of between two and four points per year can be assumed, depending on the branch use, pavement rank, and surface type. For sections that have received routine maintenance or localized repair such that the PCI has not returned to 100, the CONLOC report can be used to determine the PCI at some future time. When running that report, it should be assumed that the deterioration rate is the same as it was before the maintenance or repair. For preventive maintenance activities, the deterioration rate may either remain the same for the individual pavement section or decrease. The difference is a function of the section's past preventive maintenance history and the historical trend of past preventive maintenance strategy effectiveness at the installation. Local judgment must be used. Table 3 illustrates example calculations describing these procedures. Figures 29, 32, and 33 are graphical representations.

Budget Strategy Formulation

Budget strategy formulation is determining the installation's desired spending levels. As previously described, BUDPLAN can be used to determine the installation's budget needs based on selected criteria. However, it is difficult to use BUDPLAN to measure the effects of determining a desired network PCI at the end of some predetermined period or if the manager wants to input budget levels in different years.

Frequently, several different funding levels will produce the same or nearly the same network PCI at the end of the analysis period. However, the manager would want to develop a strategy that most improves the network, minimizes cost, or combines the two.

If a target network condition has been selected for some year in the future, a funding strategy (annual and total) must be developed to attain that goal. Tentative maintenance and repair plans must be worked out for each year in the analysis period. This is done by selecting candidate sections, applying a target strategy, and prioritizing or optimizing to meet the funding level associated with the funding strategy. (See the sections on *Selecting Candidate Sections for Major Repair and Prioritization* and *Optimization*). Network PCIs for the various years are computed (See Table 3 and the subsections on *Type and Extent of Deterioration* and *Prioritization*.) Several iterations may be needed to reach the target PCI at the end of the analysis period. Figure 44[14] illustrates the effects of different budget strategies on the overall network PCIs. The example shows the effects of the annual funding strategies as well as the total expenditure of funds.

By computing the area under each funding curve and above the "Do Nothing" curve, the effective benefit of each strategy can be computed in terms of PCI-years. The benefit of each, divided by the cost, will give a benefit/cost ratio. (Note: Multiply the ratios by like multiples of 10 to attain numbers in an easily used format.) These can be

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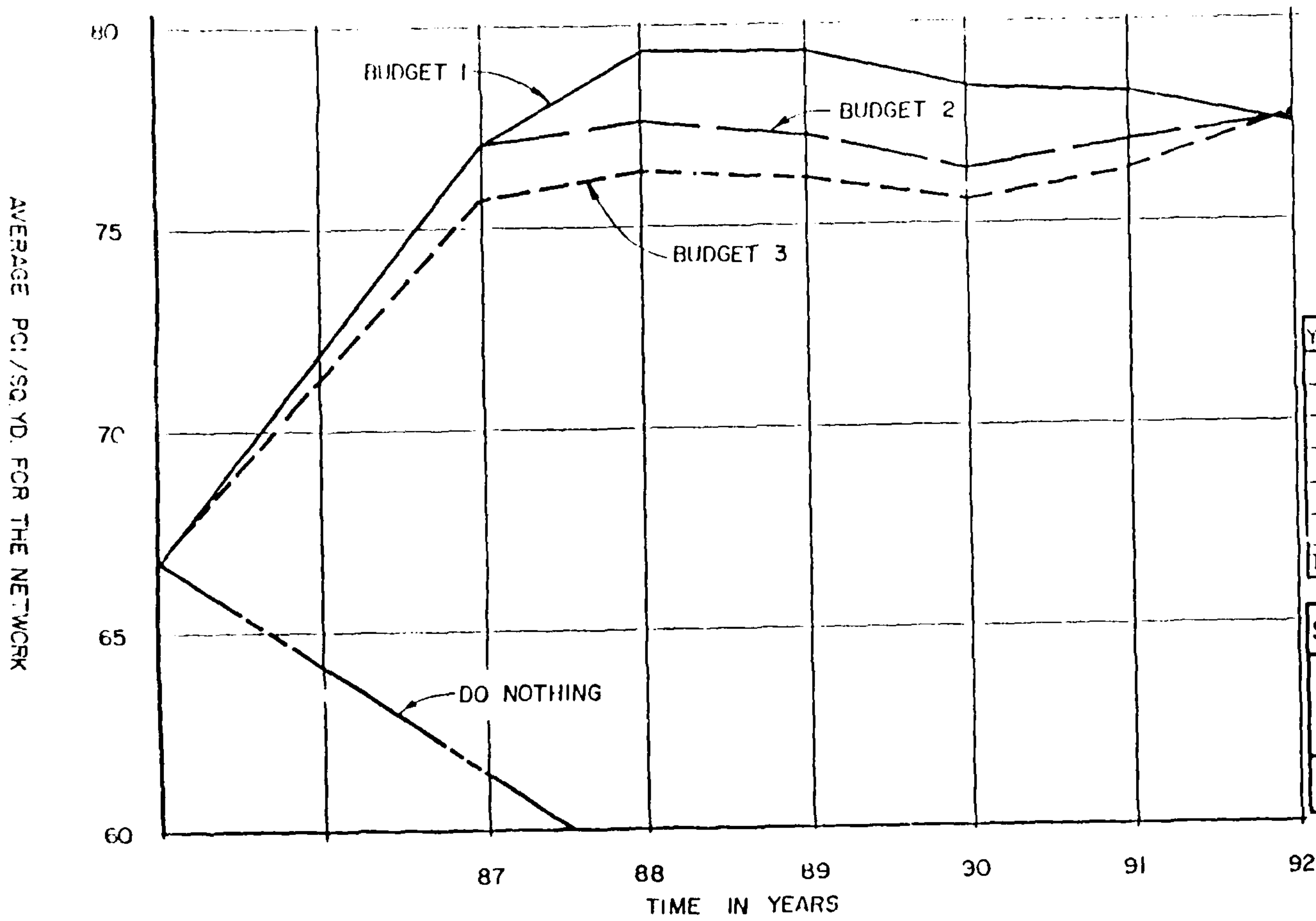
[14] *PAVER, Pavement Maintenance Management*, Prepared for Sierra Army Depot, Herlong, CA, 1985, Network Level Management Phase, Final Report (Sharp, Krater and Associates, 1985).



STRATEGY COST
(1000'S)

YEAR	1	2	3
87	749.3	749.3	499.8
88	749.2	498.2	500.0
89	487.2	439.6	497.8
90	252.1	257.7	299.7
91	174.5	267.9	286.3
92	23.2	215.4	324.8
TOTAL	2435.5	2428.4	2408.5

Strategy	1	2	3
Effective Benefit (PCI-YR)	126	119	112
B/C	.517	.490	.465

Figure 44. Example network condition for different budget strategies.

compared and used as a strategy selection factor. The strategy with the highest benefit/cost ratio should be favored.

When developing budget strategies, if projects are shifted from year to year during the analysis, project costs will also vary from year to year. (See the section on *Selecting Candidate Sections for Major Repair.*)

"What-If" Scenario Building

In facilities management, "what-if" questions are frequently asked when budgets are being prepared, revised, and so on. By using the procedures described in the previous sections, many of the "what-if" questions can be answered. Examples would be: *What* would be the effect on the pavement network *if* the pavement maintenance and repair budget were cut by 10 percent? *What* is the effect *if* a major repair project is deferred for two years? "What-if" questions for budgets are answered by matching maintenance and repair plans to the given budgets. The PCIs of the affected sections are then revised in the appropriate year, and from there, the network PCIs are calculated. 'What-if" questions about projects are answered similarly. PCIs for the individual sections within a project are revised in the year of the project execution and the overall network PCIs calculated. The results of those "what-if" questions can then be plotted to illustrate graphically what the effects are. An example is shown in Figure 45. The previous discussion on the development of prioritization and optimization strategies is an example of a "what-if" situation. Those results were illustrated as Figures 29, 32, and 33.

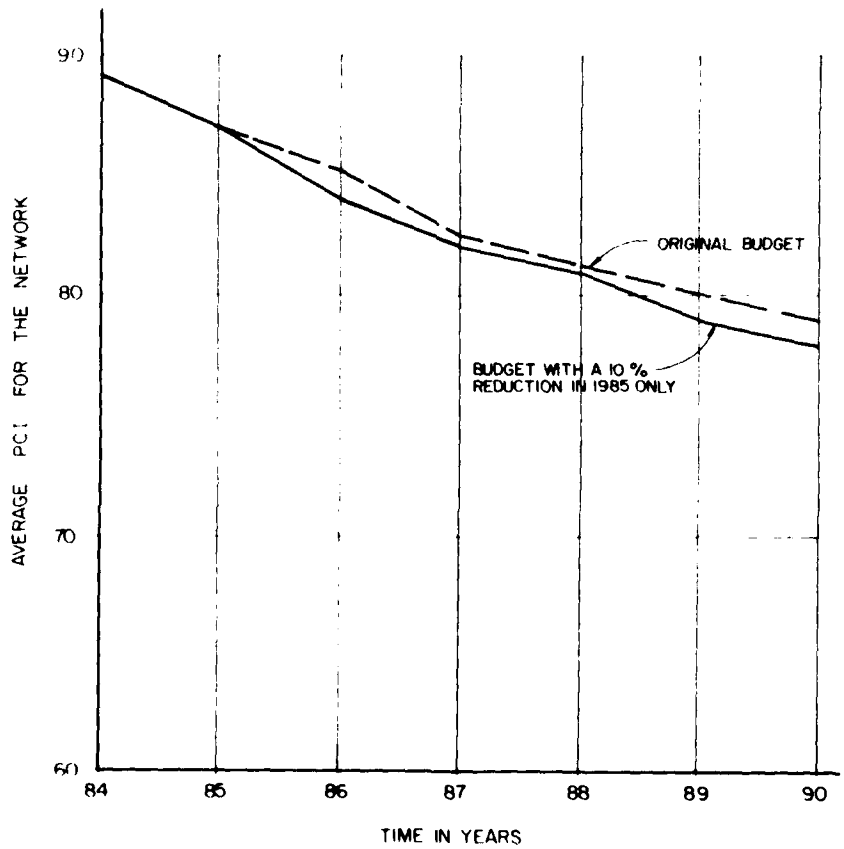


Figure 45. Example network condition for "what-if" scenario.

Network Management of Nonstandard Pavements

Nonstandard pavements are those such as gravel, brick, paving block, etc., for which a PCI cannot be calculated. To date, PCIs can be calculated only for asphalt pavements and jointed concrete pavements, although research is actively under way to develop a PCI for gravel roads. However, the lack of a PCI does not mean that those pavements cannot be managed with PAVER. They can still be sectionalized and an inventory maintained in the PAVER database. Historical information can be gathered and stored for nonstandard pavements. Also, nonstandard pavements can be inspected and a subjective pavement condition rating assigned to each section based on the inspection results. However, since the distress types have not been standardized, they cannot be entered into the PAVER database. Therefore, using PAVER to manage nonstandard pavements is limited to inventory and noninspection data storage. Inspection information, which would include the noted deficiencies and pavement condition rating, would have to be stored separately.

Feedback

The final management activity associated with managing pavements at the network level is feedback. Feedback consists of maintaining open lines of communication between the various individuals having certain responsibilities for pavements. At the network level, the primary focus would be between planners and inspectors, if these functions reside in different offices. As planners begin to develop projects, they must make certain assumptions about how well the pavement will perform after the project has been completed. The pavement inspector must routinely inspect the pavement to track its performance. Accordingly, there must be a strong line of communication between these groups, because the project planners must be informed if the pavements are not performing as expected. Modifications can then be made to both the long-range project planning strategy and the maintenance strategy. Feedback ensures that no individuals will work in a vacuum. The pavement network itself is dynamic, and proper engineering decision making requires that all appropriate personnel be aware of what is going on.

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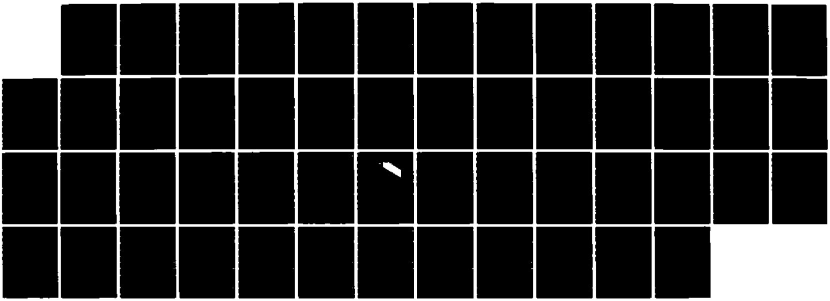

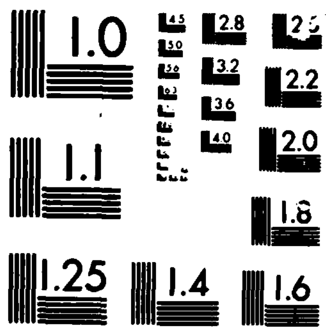

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4 MANAGING AT THE PROJECT LEVEL

Concept

Project-level management encompasses detailed management activities associated with the repair or maintenance of specific pavement sections. Management decisions are based on a detailed analysis of all available data.

Timeframe for Project-Level Management

Project-level evaluations must be performed on pavement sections just before or in conjunction with the preparation of plans and specifications for a given maintenance or repair project. In the overall management cycle, this would ordinarily be after a repair project has been planned and programmed on the basis of network-level management activities. Project-level evaluations should not be done too far in advance of the preparations of plans and specifications, since the quantities obtained from the project-level evaluation will be used in the design process.

Management Activities (Overview)

Project-level management activities are of two types: detailed pavement evaluation and maintenance/repair alternative selection, including life-cycle cost analysis. Each of these involves a number of tasks.

Detailed Pavement Evaluation Concept

So far, the network-level evaluation has produced generalized results that have been used to develop overall maintenance and repair strategies. The project-level evaluation is much more extensive and is focused on determining the cause and extent of the pavement deterioration within the pavement section. To do that requires a detailed analysis of the pavement structure. This involves an additional distress survey and gathering of other information about the existing pavement structure, materials, and expected response under loading. As discussed in detail in the literature,[15] the major questions that must be answered are as follows:

1. Is the pavement structurally adequate?

2. Is moisture causing or accelerating deterioration?

3. Is there a material durability problem?

4. Is the foundation contributing to the deterioration?

5. What is the maximum thickness that can be added to the pavement for drainage or other restrictions?

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[15] M. I. Darter, R. E. Smith, and D. R. Uzarski, *Pavement Management Systems for Urban Areas, Specialty Conference Proceedings*, "Innovative Strategies to Improve Urban Transportation Performance" (American Society of Civil Engineers, 1984).

6. Is the pavement functionally adequate (roughness, skid)?

7. What are the utility problems?

8. What are the funding constraints?

9. What are the traffic control options?

The answers to many of those questions are outside the realm of PAVER. Engineering judgment and evaluation procedures, as outlined in many engineering references, should be used where appropriate. *Techniques for Pavement Rehabilitation*[16] is an excellent reference that provides step-by-step procedures for evaluating a pavement and in formulating major repair alternatives. It can be obtained at no charge from the Federal Highway Administration (FHWA). PAVER will be used to store and retrieve that information.

Selecting the Most Feasible Maintenance/Repair Alternative Concept

The network-level evaluation produced a tentative maintenance or repair strategy. At the project level, the detailed evaluation will allow the engineer to reevaluate that strategy, determine a new listing of feasible repair alternatives, perform a life-cycle cost analysis on each alternative, and then select the preferred solution.

Performing Project-Level Inspections

Project-level inspections differ from network-level inspections. Network-level inspections involve a low sampling rate and are used primarily to determine section PCIs and the major causes of distress so that a tentative repair strategy can be formulated. Project-level inspections determine the actual repair alternative and provide an accurate estimate of material and quantities required in that repair.

Sampling Rate

Since the inspection results will be used in the detailed analysis of the section, distress types, severity, and amounts must be represented accurately. This requires a higher sampling rate than was used at the network level. Project-level inspections require a 95 percent probability that the measured PCI will be within ± 5 points of the true overall PCI. This is referred to as the 95 percent confidence interval.

The number of sample units to be inspected to meet the 95 percent confidence interval can be obtained from the INSPCUR or SAMPCUR reports (Figures 23 and 24, respectively). Because of the PCI variability among sample units, it is not uncommon for reports to recommend that 100 percent of all sample units be inspected. Accordingly, it is recommended that a 100 percent inspection policy be followed, regardless of the number of sample units recommended for inspection in the INSPCUR or SAMPCUR reports. Following this philosophy will make it unnecessary to differentiate between random and additional sample units or to worry about whether sample units represent the entire section.

[16] *Techniques for Pavement Rehabilitation* (Federal Highway Administration, 1984).

Documenting Conditions

Even though 100 percent of the sample units will be inspected, it is important that each sample unit be inspected individually and the results recorded either on the field data collection sheet (Figure 8) or directly into a portable field computer. The user should not attempt to treat the entire section as one large sample unit. Each sample unit must be inspected individually and the results entered into the PAVER database.

Additional Data Collection

Structural Capacity and Materials Evaluation

Any pavement section experiencing load-related distresses must be evaluated structurally. Once repaired, the pavement must be able to support the proposed traffic for its entire design life. A pavement that is structurally deficient and is not strengthened to carry the anticipated traffic will deteriorate rapidly, negating the effects of the repair.

The existing pavement structure can be evaluated in three basic ways: (1) analytical analysis from existing records, (2) destructive testing, and (3) nondestructive testing. Basic pavement structure information is needed for all these methods. If pavement structure information was collected and stored in the PAVER database, it can be obtained by using the RECORD report for pavement structure (Figure 46). The same is true for materials information about the different pavement layers, which can be retrieved by using the RECORD report for materials (Figure 47).

Analytical analysis from existing records will require knowledge about the existing pavement structure, material properties, and traffic volumes and loadings. PAVER will not perform the analytical analysis. It can only be used to store the specific data and retrieve it as needed. The back-calculation technique involves working backwards through the original pavement design approach to determine allowable traffic and wheel-loading levels. The allowable levels are then compared to the projected levels; if the allowable levels are less, there is a structural deficiency.

Destructive testing of the pavement section is often necessary when doing a detailed analysis. The pavement structure and/or materials information collected and stored in the PAVER database often comes from existing records. However, experience has shown that the records frequently contain erroneous information; therefore, careful consideration should be given to validating that information. Pavement structure information is most easily verified by use of pavement cores. Normally, one or two cores per section should be adequate to validate the pavement layers for type and thickness.

It may be necessary to validate the materials properties of the pavement layers. If the paving materials are believed to be contributing to the pavement distress and the materials are to be left in place either by recycling or overlay, then materials testing may be necessary. Depending on the material, samples taken from cores or test pits can be used for testing. These tests include moisture density, triaxial, resilient modulus, gradation, Atterburg limits, laboratory California Bearing Ratio (CBR), extraction, and split tensile strength. Once the material properties are known from laboratory analysis, the results can be entered into the PAVER database.

Additional testing can be in the form of in-situ field tests performed on specific pavement layers. These can include plate bearing tests, field CBRs, vane shear, etc. Again, the results of these analyses can be entered into the PAVER database.

```
AGENCY NUMBER =        011605       FT. MCNAIR

LAYER          LAYER                     THICKNESS  DATE     TYPE OF
CATEGORY      MATERIAL                     (IN)     CONST    COATING

----- PAVEMENT STRUCTURE   I1AVE  SECTION 03 - FIRST AVE
BASE          CR STONE,POOR-GRADED        8.5      10/81
*HC CORE 1 S OF C ST
LEVELING      AC                          2.0      10/81
*HC CORE 1 S OF C ST
SUBGRADE      SANDY CLAY                           10/81
*HC CORE 1 S OF C ST
SURFACE       AC                          1.5      10/81
*HC CORE 1 S OF C ST
```

Figure 46. Record (RECORD-STRUCTURE) report.

```
/
 AGENCY NUMBER =        011605       FT. MCNAIR

 ----- LAYER MATERIAL PROPERTIES   SECTION 01 - B ST

 TEST       LAYER
 DATE       CATEGORY     TEST TYPE                          TEST VALUE

 11/01/84    SURFACE     MARSHAL STABILITY                  1200.0000
 11/01/84    SURFACE     SKID                                 22.0000
 11/01/84    SURFACE     MAYS ROUGHNESS                       95.0000

$REVERT. *** END RECORD PROCEDURE ***
```

Figure 47. Record (RECORD-TEST) report.

Field testing is normally an expensive and time-consuming process; as a result, very few or no tests are done. Consequently, the use of nondestructive testing techniques is becoming very popular, since a great deal of data can be collected in very little time at reasonable cost. Normally, these tests would be performed at several locations within a pavement section. However, it is recommended that NDT be performed in conjunction with at least one pavement core per section to validate the pavement structure.

Data from the deflection testing, along with the pavement structure information, can be used to back-calculate certain parameters of the pavement structure layers. Various values that can be obtained through this process are: modulus of subgrade reaction, K; modulus of elasticity, E; and resilient modulus, E_r. Overlay design methods have also been developed that use deflection testing methods. An example is the Asphalt Institute method.[17] The Waterways Experiment Station (WES) and others describe other methodologies.[18] The general use of nondestructive testing devices with overlay design is discussed by others.[19]

Many types of nondestructive testing equipment are available and are classified in three groups: static load, vibrating steady-state force, and impulse load.

Static load nondestructive testing (NDT) is the oldest of the methods and is commonly done with a Benkelman Beam. When using this equipment, the pavement is deflected under an actual wheel load. As the vehicle very slowly moves away, the rebound deflection is measured with the Benkelman Beam. Although a Benkelman Beam is relatively inexpensive, the test procedure is very slow, and it does require a crew and a heavy truck. The slowness of the test greatly limits the amount of testing that can be done.

Vibrating steady-state force NDT devices apply a sinusoidal load to the pavement. Geophones measure the maximum deflection and the deflection basin. The most common types of vibrating steady-state force devices are the Dynaflect and the Road Rater. The Dynaflect can only apply a 1000-lb load, whereas the Road Rater, depending on the model, can apply load in excess of 16,000 lb. With thick pavement sections, caution must always be exercised when using low loads to ensure that a true structural response is obtained.

Impulse loading drops a given mass a known distance onto a loading plate. The maximum and basin deflections are then measured. This type of equipment can produce up to a 24,000-lb load, depending mostly on the mass and the drop height. This type of

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[17] *Asphalt Overlays and Pavement Rehabilitation*, Manual Series No. 17 (The Asphalt Institute, 1969).

[18] D. Coleman, *Nondestructive Vibratory Testing and Evaluation Procedures for Military Roads and Streets*, GL-84-9 (U.S. Army Waterways Experiment Station [WES], 1984); F. W. Finn and C. L. Monismith, *Asphalt Overlay Design Procedures*, NCHRP Synthesis of Highway Practice 1/6 (Transportation Research Board, National Research Council, 1984).

[19] R. L. Lytton and R. E. Smith, "Use of Nondestructive Testing in the Design of Overlays for Flexible Pavements," *Transportation Research Record 1007* (Transportation Research Board, National Research Council, 1985), pp 11-20.

equipment is known as a "falling weight deflectometer" (FWD), and research conducted at the University of Illinois has concluded that the FWD best simulates the pavement response under a moving truck.[20]

With the possible exception of the Benkleman Beam, it is very unlikely that this equipment will be available at an installation, since it is expensive and must be operated by knowledgeable personnel. Most commonly, this service is provided by consultants who will provide their own equipment, or by other agencies. For example, the Facility Engineering Support Agency (FESA) provides this service to the Army.

NDT and PAVER

Nondestructive testing information can be stored in the PAVER database, but PAVER will not analyze the data. Experienced engineering judgment must be used to properly interpret and use NDT information. The information can be retrieved from the PAVER database by either the LOOK or SPECIFY reports. (In fact, these two reports can be used to retrieve any data from the PAVER database; however, they are the only two reports that can provide NDT data.) Figures 48 and 49 provide examples of these reports.

Drainage

Whenever a pavement section is being studied for repair, the adequacy of drainage conditions should always be analyzed. Water is a prime cause of several distress types and an accelerant for others. Tables 7 and 8 from *Techniques of Pavement Rehabilitation* illustrate the effect of moisture on certain distress types.

Drainage structure information, which is easily stored in and retrieved from the PAVER database, is used on a section-by-section basis and includes items such as curb and gutter, inlets, culverts, etc. The RECORD report for drainage (Figure 50) illustrates this information.

The condition of the drainage structures and the overall ability of the pavement section to drain must be investigated during the detailed distress survey. The drainage condition should be coded for input into the database, and a brief description of the deficiencies noted on the "comments" portion of the inspection. Specific items that should be looked for in the field are:

Is the storm sewer system performing as designed?

Are inlets and culverts clear and set at proper elevations?

Is water standing on the pavement?

Where appropriate, are ditch lines clear and free of standing water? Inspectors should always be aware of moisture-induced distress or distresses that can enhance moisture damage.

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[20]M. R. Thompson and M. J. Hoffman, *Mechanistic Interpretation of Nondestructive Pavement Testing Deflections*, Technical Report UILU-ENG-81-2010, University of Illinois, Civil Engineering Studies, Transportation Engineering Series No. 32, Illinois Cooperative Highway and Transportation Series No. 190 (1981).

```
LIST C103,C1002,C3204,C3301,C3302,C3304,C3305,OB C3301 WH C3204 EQ NO. 1;
  BRANCH NUMBER   SECTION NUMBER   TEST SERIES   TIME OF TEST   LOCATION-STATION   SURFACE TEMPERATURE   AIR TEMPERATURE
***
* I4AVE           02               NO. 1                  801   0.00                              80.6              78.0
* I4AVE           02               NO. 1                  802   100                               80.6              78.0
* I4AVE           02               NO. 1                  803   200                               80.6              78.0
* I4AVE           02               NO. 1                  804   300                               87.8              87.0
* I4AVE           02               NO. 1                  805   400                               87.8              87.0
* I4AVE           02               NO. 1                  806   500                               87.8              87.0
* I4AVE           02               NO. 1                  807   600                               92.3              83.0
* I4AVE           02               NO. 1                  808   700                               92.3              83.0
* I4AVE           02               NO. 1                  809   800                               92.3              83.0
* I4AVE           02               NO. 1                  810   900                               92.3              83.0
* I4AVE           02               NO. 1                  811   1000                              92.3              83.0
* I4AVE           02               NO. 1                  812   1100                              92.3              83.0
* I4AVE           02               NO. 1                  813   1200                              92.3              83.0
* I4AVE           02               NO. 1                  814   1300                              92.3              83.0
* I4AVE           02               NO. 1                  815   1400                             101.3              87.0
* I4AVE           02               NO. 1                  816   1500                             101.3              87.0
* I4AVE           02               NO. 1                  817   1600                             101.3              87.0
* I4AVE           02               NO. 1                  818   1700                             101.3              87.0
* I4AVE           02               NO. 1                  819   1800                             101.3              87.0
* I4AVE           02               NO. 1                  820   1900                             101.3              87.0
* I4AVE           02               NO. 1                  821   2000                             109.4              90.0
* I4AVE           02               NO. 1                  822   2100                             109.4              90.0
* I4AVE           02               NO. 1                  823   2200                             109.4              90.0
* I4AVE           02               NO. 1                  824   2300                             109.4              90.0
* I4AVE           02               NO. 1                  825   2400                             109.4              90.0
* I4AVE           02               NO. 1                  826   2500                             109.4              90.0
* I4AVE           02               NO. 1                  827   2600                             109.4              90.0
---
```

Figure 48. Immediate access (LOOK) report.

```
LIST C1201,C1202,C1203,C1204,C1207,C1208;
  DEVICE ID DESC   PLATE DIAMETER   DIAMETER UNITS   NUMBER OF SENSORS      MASS   MASS UNITS
***
* STATC                                                              1      9000   LBS
---


LIST C1301,C1302,C1303,C1304,C1305;
  LAYOUT ID DESC   DISTANCE UNITS   SENSOR 1 DISTANCE   SENSOR 1 OFFSET   LOADED/UNLOADED 1
***
* BEAM1            FT                             8.0   0.0               U
---


LIST C103,C1002,C3201,C3202,C3204,C3203,C3205 WH C3204 EQ NO. 1;
  BRANCH NUMBER    SECTION NUMBER   DEVICE ID   LAYOUT ID   TEST SERIES   NDT TEST DATE   TEST SERIES DESCRIPTION
***
* I4AVE            02               STATC       BEAM1       NO. 1            09/12/1985   AT CENTERLINE
---


LIST C103,C1002,C3204,C3203,C3206,C3207,C3208 WH C3204 EQ NO. 1;
  BRANCH NUMBER    SECTION NUMBER   TEST SERIES   NDT TEST DATE   NUMBER OF TESTS   TEST INTERVAL   INTERVAL UNITS
***
* I4AVE            02               NO. 1            09/12/1985                27           100.0   FT
---


LIST C103,C1002,C3204,C3203,C3209,C3211,C3210 WH C3204 EQ NO. 1;
  BRANCH NUMBER    SECTION NUMBER   TEST SERIES   NDT TEST DATE   REP AIR TEMP   REP PAVEMENT TEMP   TEMP UNITS
***
* I4AVE            02               NO. 1            09/12/1985           82.0                94.2   F
---


LIST C103,C1002,C3204,C3203,C3213,C3214 WH C3204 EQ NO. 1;
  BRANCH NUMBER    SECTION NUMBER   TEST SERIES   NDT TEST DATE   REP SERIES LOAD   REP SERIES LOAD UNITS
***
* I4AVE            02               NO. 1            09/12/1985              9000   LB
---


LIST C103,C1002,C3204,C3203,C3228,C3235,C3227 WH C3204 EQ NO. 1;
  BRANCH NUMBER    SECTION NUMBER   TEST SERIES   NDT TEST DATE   REP SERIES DEFL 1   REP SERIES DEFL 1 STD DEV   REP SERI
UNITS
***
* I4AVE            02               NO. 1            09/12/1985                 5.3                         1.4   MM

---
```

Figure 48 (Cont'd).

```
LIST BY C0,C103,C1002,C3204,C3203,C3301,C3302,C3704,OB C3301 WH C3301 EXISTS;
-339- NOTE - ORDERING ITEMS BELOW PRINT ITEMS -
  BRANCH NUMBER    SECTION NUMBER    TEST SERIES    NDT TEST DATE    TIME OF TEST   LOCATION-STATION      DEFL 1
***

* I4AVE            02                NO. 1              09/12/1985            816   1500                     4.8
*                                                                             808   700                      5.6
*                                                                             824   2300                     4.8
*                                                                             804   300                      7.4
*                                                                             820   1900                     7.1
*                                                                             812   1100                     6.6
*                                                                             826   2500                     5.6
*                                                                             802   100                      6.1
*                                                                             818   1700                     5.1
*                                                                             810   900                      5.6
*                                                                             825   2400                     4.1
*                                                                             806   500                      5.6
*                                                                             822   2100                     7.4
*                                                                             814   1300                     5.6
*                                                                             827   2600                     5.1
*                                                                             801   0.00                     7.8
*                                                                             817   1600                     4.3
*                                                                             809   800                      5.1
*                                                                             821   2000                     7.1
*                                                                             805   400                      6.6
*                                                                             819   1800                     6.9
*                                                                             813   1200                     6.4
*                                                                             823   2200                     2.5
*                                                                             803   200                      8.6
*                                                                             811   1000                     6.1
*                                                                             807   600                      3.8
*                                                                             815   1400                     5.3
---
```

Figure 48 (Cont'd).

1

SPECIFY REPORT
85/10/10.

DEV ID DESC	NUM OF SENS	MASS	MASS UN
***			
* STATC	1	9000	LBS

1

SPECIFY REPORT
85/10/10.

LAYOUT ID DES	SEN 1 DIST	SEN 1 OFFSET
***		
* BEAM1	8.0	0.0

1

SPECIFY REPORT
85/10/10.

BRANCH NUMBER	SEC #	DEV ID	LAY ID	TEST SERIES	TEST SERIES DESC.	NUM TEST	TEST INTVAL	IN UN
***								
* I4AVE	02	STATC	BEAM1	NO. 1	AT CENTERLINE	27	100.0	FT

1

SPECIFY REPORT
85/10/10.

BRANCH NUMBER	SEC #	DEV ID	LAY ID	TEST SERIES	NDT TEST DATE	REP AIR TEMP	REP PAV TEMP	TEMP UN
***								
* I4AVE	02	STATC	BEAM1	NO. 1	09/12/1985	82.0	94.2	F

1

SPECIFY REPORT
85/10/10.

BRANCH NUMBER	SEC #	TEST SERIES	NDT TEST DATE	REP SER DEF 1	REP SER DF 1 STD DEV	REP SER DEF UN
***						
* I4AVE	02	NO. 1	09/12/1985	5.3	1.4	MM

Figure 49. Data items (SPECIFY) report.

1

SPECIFY REPORT
85/10/10.

TEST SERIES	NDT TEST DATE	TIME TEST	LOC. STAT.	LOCATION OFFSET	SURF TEMP	AIR TEMP	LOAD	DEFL 1
***								
* NO. 1	09/12/1985	801	0.00	0	80.6	78.0	9000	7.8
*		802	100	0	80.6	78.0	9000	6.1
*		803	200	0	80.6	78.0	9000	7.4
*		804	300	0	87.8	87.0	9000	8.6
*		805	400	0	87.8	87.0	9000	6.6
*		806	500	0	87.8	87.0	9000	5.6
*		807	600	0	92.3	83.0	9000	3.8
*		808	700	0	92.3	83.0	9000	5.6
*		809	800	0	92.3	83.0	9000	5.1
*		810	900	0	92.3	83.0	9000	5.6
*		811	1000	0	92.3	83.0	9000	6.1
*		812	1100	0	92.3	83.0	9000	6.6
*		813	1200	0	92.3	83.0	9000	6.4
*		814	1300	0	92.3	83.0	9000	5.6
*		815	1400	0	101.3	87.0	9000	5.3
*		816	1500	0	101.3	87.0	9000	4.8
*		817	1600	0	101.3	87.0	9000	4.3
*		818	1700	0	101.3	87.0	9000	5.1
*		819	1800	0	101.3	87.0	9000	6.9
*		820	1900	0	101.3	87.0	9000	7.1
*		821	2000	0	109.4	90.0	9000	7.1
*		822	2100	0	109.4	90.0	9000	7.4
*		823	2200	0	109.4	90.0	9000	2.5
*		824	2300	0	109.4	90.0	9000	4.8
*		825	2400	0	109.4	90.0	9000	4.1
*		826	2500	0	109.4	90.0	9000	5.6
*		827	2600	0	109.4	90.0	9000	5.1

Figure 49 (Cont'd).

AGENCY NUMBER = 011605 FT. MCNAIR

TYPE	DRAINAGE DESCRIPTION	DRAINAGE LOCATION	LENGTH(LF)
----- DRAINAGE		SECTION 03 - FIRST AVE	
SURFACE	DITCH(FILL) OVER 4 FT DEE	185' N OF S TO 1321' W SIDE	1136
SURFACE	C&G,INLET IN GUTTER	593' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	563' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	2589' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	2494' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	2297' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	2195' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	1957' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	1845' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	184' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	1574' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	1444 N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	129' W OF E S SIDE	
SURFACE	C&G,INLET IN GUTTER	129' W OF E N SIDE	
SURFACE	C&G,INLET IN GUTTER	1126' N OF S E SIDE	
SURFACE	C&G,INLET IN GUTTER	1064' N OF S E SIDE	

Figure 50. Record (RECORD-DRAINAGE) report.

Table 7

Moisture-Related Distress in Asphalt Pavement

Type	Distress Manifestation	Moisture Problem	Climatic Problem	Material Problem	Load Associated	Structural Defect Begins in: Asphalt	Base	Subgrade
Surface Defect	Abrasion	No	No	Aggregate	No	Yes	No	No
	Bleeding	No	Accentuated by high temp.	Bitumen	No	Yes	No	No
	Raveling	No	No	Aggregate	Slightly	Yes	No	No
	Weathering	No	Humidity and light-dried bitumen	Bitumen	No	Yes	No	No
Surface Deformation	Bump or distortion	Excess moisture	Frost heave	Strength-moisture	Yes	No	Yes	Yes
	Corrugation or rippling	Slight	Climatic and suction relations	Unstable mix	Yes	Yes	Yes	Yes
	Shoving	No		Unstable mix; loss of bond	Yes	Yes	No	No
	Rutting	Excess in granular layers	Suction and material	Compaction properties	Yes	Yes	Yes	Yes
	Waves	Excess	Suction and materials	Exp. clay; frost susc.	No	Not initially	No	Yes
	Depression	Excess	Suction and materials	Settlement, fill material	Yes	No	No	Yes
	Potholes	Excess	Frost heave	Strength-moisture	Yes	No	Yes	Yes
Cracking	Longitudinal	Yes strength loss	Spring-thaw		Yes	Faulty construction	Yes	Yes
	Alligator	Yes; Drainage		Possible mix problems	Yes	Yes, mix	Yes	Yes
	Transverse	Yes	Low-temp. F-T cycles	Thermal properties	No	Yes, temp susceptible	Yes	Yes
	Shrinkage	Yes	Suction, moisture loss	Moisture-sensitive	No	Yes, hardening	Yes	Yes
	Slippage	Yes	No	Loss of bond	Yes	Yes, bond	No	No

Table 8

Moisture-Related Distress in PCC Pavement

Type	Distress Manifestation	Moisture Problem	Climatic Problem	Material Problem	Load Associated	Structural Defect Begins in: Surface	Base	Subgrade
Surface Defects	Spalling	Possible	No		No	Yes	No	No
	Scaling	Yes	F-T Cycling	Chemical influence	No	Yes, finishing	No	No
	D-Cracking	Yes	F-T Cycling	Aggregate	No	Yes	No	No
	Crazing	No	No	Rich mortar	No	Yes, weak surface	No	No
Surface Deformation	Blowup	No	Temperature	Thermal properties	No	Yes	No	No
	Pumping	Yes	Moisture	Fines in base moisture-sensitive	Yes	No	Yes	Yes
	Faulting	Yes	*Moisture-suction*	*Settlement* deformation	Yes	No	Yes	Yes
	Curling	Possible	Moisture and temp.		No	Yes	No	No
Cracking	Corner	Yes	Yes	Follows pumping	Yes	No	Yes	Yes
	Diagonal Transverse Longitudinal	Yes	Possible	Cracking follows moisture buildup	Yes	No	Yes	Yes
	Punch Out	Yes	Yes	Deformation following cracking	Yes	No	Yes	Yes
	Joint	Produces damage later	Possible	Proper filler and clean joints	No	Joint	No	No

A complete drainage survey and evaluation should be conducted if necessary. The procedures are outlined in *Techniques for Pavement Rehabilitation*. The need for properly recognizing actual or potential moisture damage cannot be overemphasized. Failure to correct moisture problems in the major repair project will lead to rapid degradation of the pavement section.

Traffic

To properly evaluate an existing pavement or to design a new pavement, the engineer must know what traffic the pavement must bear. Traffic volumes and types are both important.

The U.S. Army Military Transportation Management Command (MTMC) performs traffic surveys periodically at most military installations. These surveys generally provide average daily traffic (ADT) for given pavements. While ADTs can be very useful for pavement evaluation and design, it is more important to know the traffic mix, especially the heavy vehicles that are and will be using the pavement in the future. During this project-level evaluation, it will be very useful to do traffic surveys of the pavement sections under consideration. The traffic mix in terms of vehicles per day and, if possible, the axle load should be obtained. In many cases, the weigh information can be obtained by interviewing the truck driver. Once obtained, traffic information can be entered into the PAVER database and retrieved via the RECORD report (Figure 51) for traffic. TM 5-623 and USA-CERL Technical Report M-294 describe how to break traffic down into standard categories and how to calculate a volume index for each type of traffic.

```
AGENCY NUMBER =        011605       FT. MCNAIR

----- TRAFFIC RECORD                SECTION 03 - FIRST AVE

              TRAFFIC TYPE                   VOLUME/UNITS     VOLUME INDEX

SURVEY DATE-  11/10/83
   2-AXLE TRUCKS-BUSES,TRACKED VEHICLES LT
   20 KIP,FORKLIFTS LT 5 KIP                                         1

   PASSENGER,PANEL,PICKUP                                            2
```

Figure 51. Record (RECORD-TRAFFIC) report.

Additional Condition Indicators

Additional condition indicators are parameters other than PCI and inspection data that will directly affect the selection and analysis of repair alternatives. These indicators may include ride quality, safety, accident rates, and user complaints. Although generally subjective, these indicators may provide useful information about the section that probably were not considered at the network level. Once this information is compiled, the extent of the repair project may be found to extend beyond the pavement itself. This information is most easily obtained during the distress survey. An overall condition of roughness, skid, etc., can be entered into the database with the other inspection results.

If deemed necessary by the engineer, surface roughness measurements and skid resistance measurements can be obtained with specialized equipment. Roughness meters, such as a Mays Meter or profilometers, can be used to measure certain pavement parameters related to roughness. Consultants who have access to this equipment will most likely have to be hired to gather this information. Use of this equipment may be expensive and may not be necessary, especially where speeds are low. It may be just as appropriate to ride over the road at the posted speed limit and rate the ride quality subjectively, using engineering judgment. The ride quality could be converted to minor, moderate, or major severity and then noted on the section evaluation summary. This data can also be stored and retrieved from the PAVER database. For airfield pavements, pilots' complaints may be an important consideration in determining surface roughness. If complaints have been received, detailed roughness surveys should be considered.

Skid resistance is an important safety consideration. Although not generally a problem on low-speed roads, it may become very important for runways and high-speed taxiways. Skid resistance measurements can be obtained with measuring devices such as a Mu Meter. Skid surveys for airfield pavements are routinely performed by the various military agencies. If appropriate, the latest survey should be obtained and considered during this evaluation. Skid numbers can be stored and retrieved from the PAVER database. For roads and streets, specific consideration should be given to distresses such as polished aggregate, and to depressions and rutting where water can accumulate, thereby causing hydroplaning problems. Accident records may be useful for pinpointing where accidents caused by skids have occurred.

Alignment and geometric improvements may also be necessary, and if so, should be done with the pavement repair.

Pavement Evaluation

Once all available information for the pavement section under study has been collected, the engineer must evaluate those data in detail. The Section Evaluation Summary (Figure 15) which was used in the network-level evaluation, will be used again at the project level. The same questions will be answered, but at the project level, and detailed information will be used.

Strip Map

A strip map is recommended to help perform the section evaluation. The strip map should lay out the section, station by station and sample unit by sample unit. Pertinent information that has been collected and retrieved from the database should be plotted. Specific items of interest that should be shown on the map are PCI by sample unit, deflection profile, moisture problems, and key distresses. Figure 52 is an example of a

INSTALLATION NAME	BRANCH NAME	BRANCH NO.	SECTION NO.	PAVEMENT RANK	WIDTH	LENGTH	AREA	PCI
VINTAGE HILL FARMS STATION	PATROL ROAD	IVPAT	06		LF	LF	10153 S.Y.	74

INSPECTION DATE 2/10/84
SURFACE TYPE AC

DISTRESS EVALUATION
% LOAD 58.9
% CLIMATE/DURABILITY 31.1
% OTHER 10.0

COMMENTS

LOCALIZED VARIATION
MAJOR DISTRESS OV/H
NO MOISTURE DAMAGE
DISTRESS CAUSED BY
CROSS TRAFFIC

FOR OTHER SAMPLE UNITS
MAJOR DISTRESSES ARE:
03/L,M,H; 10/L,M; 07/L,M
AVE PCI FOR ALL SAMPLE UNIT
EXCEPT 9 86

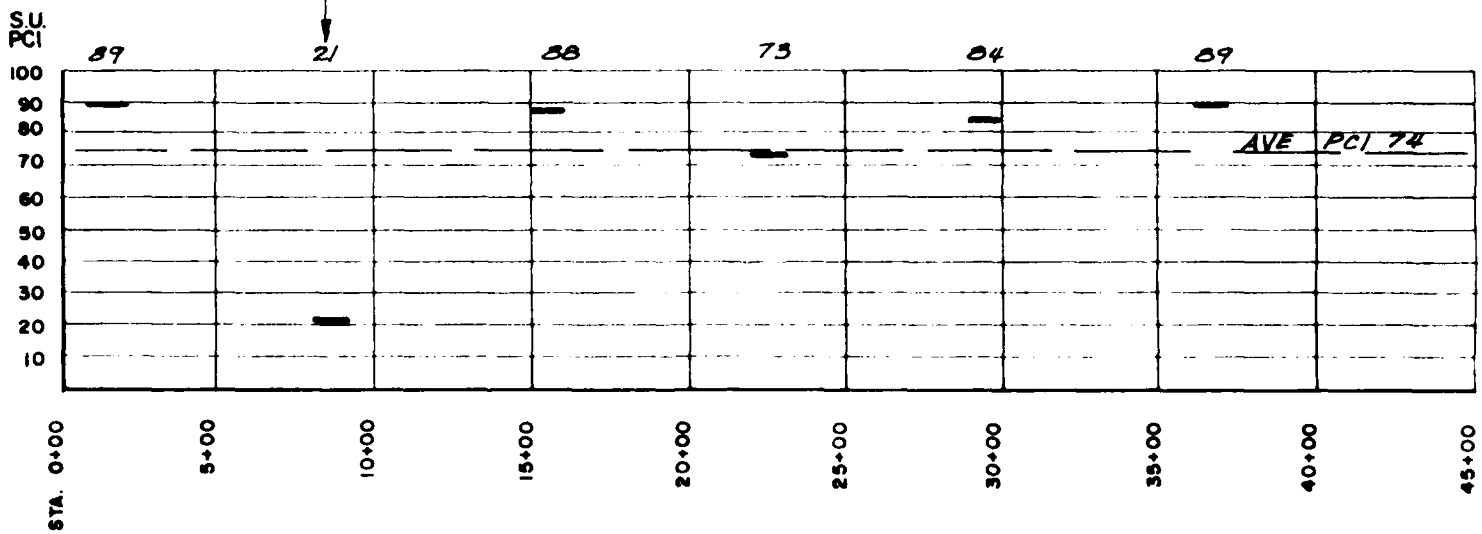

Figure 52. Example strip map.

strip map that shows such information. This map is quite beneficial; the engineer can see at a glance if a section is deteriorating uniformly or if systematic or localized variation has occurred. Depending on the variation, if any, and the length of the section, it may be prudent to split the section into two or more parts and apply a separate repair strategy to each. The PCIs, deflections, specific distresses, and moisture may indicate the need for major patching in conjunction with the overall repair strategy planned for the section. To help develop the strip map, it will be useful to refer to the section identification record and possibly to the Inventory (INV) report or RECORD report for identification (Figures 3, 53, and 54, respectively).

Section Evaluation Summary

For the section evaluation summary, information can be obtained from the strip map about the overall section PCI, variation of PCI, the distress evaluation, including cause and moisture effects, and load-carrying deficiencies. The rate of deterioration, both long- and short-term, can be determined in a similiar fashion as was done at the network level. (See discussion in Chapter 3.)

Past Maintenance

Knowledge of past maintenance on the pavement section is important and should be studied carefully. Past maintenance records should be studied, and if past information has been entered into the PAVER database, it can be obtained by using the Work History (WORKHIS) report (Figure 55). By studying past maintenance on the section, the engineer can gain an insight into the section's symptomatic problems. Knowing what has already been done, its location, and any recurrences can be particularly useful. Also, the past work history often extends back several years, well before distress surveys were done. Thus, this information will help the engineer ascertain the historical pavement condition.

Past Designs for the Section

Past rehabilitation designs for the pavement sections under study should be evaluated on the basis of performance. This information will be helpful in developing new designs for the pavement section. If past designs have not been performing as expected, the reasons for their lack of adequate performance should be studied. The assumptions and parameters used in those designs should be re-evaluated and the shortcomings overcome. Also, past designs that *have* performed well should be considered for future designs.

Repair Alternative Formulation

Several repair or maintenance alternatives can be applied for any given pavement section. A tentative strategy has already been assigned to the section at the network level, but the project-level evaluation considers much more information. The tentative strategy that was developed at the network level should be used as a starting point in developing new alternatives. The procedures for designing a pavement or overlay are beyond the scope of this report, but the engineer should always remember that when developing alternatives, it is critically important to repair the pavement adequately to eliminate or reduce the factors that led to its deterioration.

AGENCY NUMBER = 011605 FT. MCNAIR

REPORT DATE- 04/08/85

INVENTORY
SECTION CATEGORY TYPE N

	SURF TYPE	BRANCH USE	PAVEMENT RANK	AREA (SY)
I5AVE FIFTH AVE				
SECTION 01 FROM- LAMP POST B & 5 TO- 268' N END CURB E	AC	ROADWAY	SECONDARY	774
SECTION 02 FROM- S CURB B ST TO- 200' S S CURB B	AC	ROADWAY	SECONDARY	400
SECTION 03 FROM- N CURB GATE 2 ST TO- E CURB 4TH AVE	AC	ROADWAY	SECONDARY	1222
SECTION 05 FROM- E CURB 4 AVE TO- W CURB 5 AVE	AC	ROADWAY	TERTIARY	394
SECTION 06 FROM- 200' S OF B ST TO- 500' S OF B ST	AC	ROADWAY	SECONDARY	600
SECTION 07 FROM- 500' S OF B ST TO- N SIDE POOL LOT	AC	ROADWAY	SECONDARY	1140
SECTION 08 FROM- N SIDE POOL LOT TO- N CURB AT GATE 2 ST	AC	ROADWAY	SECONDARY	1786
			TOTAL BRANCH AREA	6316

TOTAL AREA OF SELECTED SECTION CATEGORY N PAVEMENTS 6,316

Figure 53. Inventory (INV) report.

```
AGENCY NUMBER =        011605       FT. MCNAIR

*******************************

                          SECTION IDENTIFICATION

BRANCH#-   I1AVE                       AREA-             6933 SY
BR NAME-   FIRST AVE                   LENGTH-                LF
SEC#-      03                          WIDTH-                 LF
FROM-      S CURB B ST                 BRANCH USE-      ROADWAY
TO-        W CURB 2 AVE                PAVEMENT RANK-   SECONDARY
SURFACE-   AC                          SECTION CATEGORY-  N
ZONE-      FTMN                        SLAB WIDTH-
                                       SLAB LENGTH-
```

Figure 54. Record (RECORD-ID) report.

```
REPORT DATE-  04/15/85              WORK HISTORY

AGENCY NUMBER =        011605       FT. MCNAIR

                          SECTION CATEGORY TYPE N   PAVEMENTS
```

SECTION IDENTIFICATION	WORK DESCRIPTION	MTL CODE	MANNER ACCOMP	DATE COMPL	IN-PLACE UNIT COST	TOTAL COST
B ST FAC #IBSTR SEC 01						
	CRACK FILLING	171	IN HOUSE	03/82	1.10/LF	1713
	DEEP PATCH 2.00 IN	120	IN HOUSE	08/82	2.50/SF	1250
	OVERLAY 2.50 IN	120	BY CONTRACT	03/85	13.02/SY	5287

$REVERT. *** END WORKHIS PROCEDURE ***

Figure 55. Work history (WORKHIS) report.

Tentative Designs

As alternatives are developed, actual tentative designs must be determined for each one in order to estimate quantities and costs for a life-cycle cost analysis. The designs are also considered tentative because as the project enters the final plans and specifications preparation phase, some modifications can be expected. Even though the designs are tentative, care should be taken to make sure that they are reasonably specific. Sufficient data are available from the project-level evaluation to do these specific tentative designs. The INV, RECORD, INSPCUR, SAMPCUR, and MRG reports should all be used to obtain quantity information for given pavement sections.

An example of a tentative design would be a 2-1/2-in. overlay with all high-severity alligator cracking being patched. The overlay thickness should have been based on the deflections of the areas without high-severity alligator cracking. A second tentative design for the same section might be a 2-in. overlay with high- and medium-severity alligator cracking areas being patched. Other tentative designs are also possible. Although these examples are overly simplified for illustration, it can be seen that several repair alternatives are valid for a given pavement section.

Estimating Performance

One of the engineer's most difficult tasks is determining the performance of a given tentative design. Ideally, for major repair, reconstruction, overlays, etc., the pavement will reach a *minimum acceptable PCI* at the end of the design life. Unfortunately, there are no procedures for designing on that basis. Except for airfield pavements, there is no reliable analytical method for estimating the performance of various designs, thereby making it very difficult for comparing long-term performance to study the differences between, say, the 2-1/2-in. overlay with patched high-severity alligator cracking and a 2-in. overlay with patched high- and medium-severity alligator cracking. Although research in this area is being pursued, it is recommended that for the time being, local engineering judgment and experience on the performance of given designs be used in this process.

Airfield Pavement Performance

It is possible to predict airfield pavement performance. For asphalt concrete (AC) pavements, the Volume 7 (VOL7) report will do a PCI prediction based on age, thicknesses of layers, layer strength parameters, and aircraft. For Portland Cement Concrete (PCC) pavements, the input required is slab replacement and patching percentages, joint spacing, annual temperature, freeze index, stresses, and concrete modulus of rupture. Known PCI information can also be entered for both AC and PCC pavements. These reports are particularly useful for showing the effects on performance of varying design parameters. Figures 56 and 57 illustrate the VOL7 report for both AC and PCC pavements. This is thoroughly described by Shahin, et al.[21]

Information Sources

PAVER will not perform a pavement design, but rather will be used in a decision support role to store and analyze pertinent information needed in the design process.

---

[21] M. Y. Shahin, M. I. Darter, and T. T. Chen, *Development of a Pavement Maintenance Management System, Vol VII: Maintenance and Repair Consequence Models and Management Information Requirements*, ESL-TR-79-18 (December 1979).

```
AMEDEE AIRFIELD

     C141 AIRCRAFT ID
       .0 AGE BETWEEN ORIGINAL CONSTRUCTION AND LAST OVERLAY
      3.0 TOTAL AC THICKNESS IN INCHES INCLUDING OVERLAYS
     15.0 TOTAL PAVEMENT THICKNESS ABOVE SUBGRADE
     80.0 CBR OF BASE
     25.0 CBR OF SUBGRADE

     18.0 YEARS TO OVERLAY FROM LAST CONST/OVERLAY
      2.0 THICKNESS OF OVERLAY


  AGE SINCE OVERLAY        PCI
  -----------------        ---
             .0          100.0
            5.0           77.2
           10.0           54.4
           15.0           31.7
           20.0            8.9
```

Figure 56. PCI prediction (VOL7) report for AC airfield pavements.

```
AMEDEE AIRFIELD APRON

       .0 % OF TOTAL SLABS REPLACED
     25.0 LONGEST JOINT SPACING (IN FEET)
     24.5 SHORTEST JOINT SPACING
     49.5 AVERAGE ANNUAL TEMPERATURE (F)
    200.0 FREEZING INDX (DEGREE DAYS BELOW 32F)
       .0 % OF TOTAL SLABS CONTAINING LARGE PATCHES (OVER 5 FT)
          OR % OF TOTAL AREA PATCHED IF OVERLAID WITH ASPHALT
    750.0 MODULUS OF RUPTURE
    375.0 INTERIOR STRESS
       -- NO ASPHALT OVERLAY

      5.0 AGE AT WHICH AIRCRAFT CHANGES
    320.0 NEW CONCRETE INTERIOR STRESS


  AGE SINCE LAST CONST/OVERLAY          PCI
  ----------------------------          ---
                    .0                100.0
                   5.0                 89.1
                  10.0                 79.0
                  15.0                 68.9
                  20.0                 58.7
```

Figure 57. PCI prediction (VOL7) report for PCC airfield pavements.

Proper use of this information is in conjunction with standard design practices and references. Some of these references include county soil reports, overlay design procedures for specific nondestructive testing devices, state specifications for highway construction, agency design manuals, and contractor statements of work. Full consideration should be given to each of these where appropriate. Contractors in the United States are familiar with state specifications for road and street construction, and it will be their plants that produce the construction materials. Since the use of state and county specifications can be of tremendous value in reducing construction costs, the engineer preparing the tentative designs should be familiar with them in order to prepare proper, feasible alternatives.

Feasible Versus Infeasible Alternatives

Several alternatives are plausible for any given project; however, some may not be feasible. Therefore, the engineer should first consider each alternative from a feasibility perspective. Although an option may be viable and incorporate sound engineering judgment and analysis, external factors may preclude its being feasible. For example, although recycling is common in parts of the country and its merits have been proven again and again, it is still unheard of in certain geographic areas. A contractor needs specialized equipment to do recycling. If the contractor does not have this equipment and is unwilling to make the capital outlay to do the installation's project at a reasonable price, then the alternative is not feasible.

It is recommended that outside investigation be done on all tentative designs to determine if those specific alternatives have been successfully accomplished locally. If possible, the performance of those alternatives should also be determined. Here, interface with city, county, and state agencies can be very valuable.

Life-Cycle Cost Analysis

A life-cycle cost analysis must be performed for each feasible alternative developed. The results are one of the most important considerations for selecting the most feasible alternative. The costs that should be considered in a life-cycle cost analysis include construction costs, future maintenance costs, future rehabilitation costs, salvage value, and user costs.

User costs are normally ignored in the analysis because of the difficulty in estimating them. Salvage value may be a consideration in the cost, depending on the planned use of the pavement after the analysis, but typically, these costs are also commonly ignored. The primary considerations then are construction costs and future maintenance and rehabilitation costs.

Construction Cost Estimating

Construction costs will be determined by standard estimating procedures. The first step will be to determine the quantities needed. This must include all items pertinent to the project, such as relocation of secondary structures, shoulders, earthwork (if applicable), pavement layers, and drainage improvements (if applicable). To the degree that these designs are developed, some of the estimates may be quite rough, but as long as the estimates are reasonable, a valid analysis can be done. After quantities have been estimated, the unit prices should be developed.

Several PAVER reports can be used to help determine project quantities and prices. The detailed analysis and inspection conducted at the project level produces accurate quantity information. The information used to estimate repair costs for specific distresses is stored in the database under Maintenance and Repair Policy and is based on a generalized maintenance policy practice. When the policy is established, certain assumptions must be made about project size and manner of accomplishment. Now that the project is being defined accurately for a given set of circumstances and conditions, the unit costs may require revision. These costs will *not* include major items such as overlay, recycling, and reconstruction. These must be estimated from local construction prices and estimating guides.

Future Cost Estimating

Future maintenance and rehabilitation costs must be estimated for use in the life-cycle cost analysis. The first step is determining the type and frequency of work to be accomplished. The engineer must also make a reasonable assumption about the major rehabilitation work that the pavement section will require at the end of its design life.

Estimating these future costs requires only making a reasonable estimate in terms of current dollars. For example, if preventive maintenance for a given pavement section would cost $5000 today, it can be assumed that this same $5000 figure will apply in the future. Procedures for doing the life-cycle analysis will use inflation and interest factors to adjust current costs for the future.

Economic Analysis

Once the cost and reasonable estimate of the performance life for each alternative have been developed, an economic analysis can be done to compare the alternatives.

Two PAVER reports can be used to do an economic analysis: the Present Worth Analysis (ECON) and the Equivalent Uniform Annual Cost (ECON 1) reports. Both of these methods allow the user to evaluate sections on the basis of economics. Both are interactive reports that do not access the PAVER database. All required input for the analysis must be entered when the report is run. These data include the interest rate, inflation rate, analysis period, fiscal year to start analysis, activity date and cost, and salvage value.

The interest rate is the standard rate expected if the money were put into an alternate investment, such as a bank account. This interest rate and the inflation rate are usually set by the agency.

The ECON report converts all costs, both present and future, to a present value. To compare alternatives properly, the analysis period for all the alternatives must be the same. If one alternative has a longer life than another, the analysis period will be the common multiple of the two alternative lives. For example, if one alternative has a life of 10 years and another has a life of 20 years, then the analysis period will be 20 years. For the 10-year alternative, this will require that a major rehabilitation be costed after year 10. Figure 58 illustrates the ECON report.

The ECON 1 report provides the same present worth analysis as the ECON report, but it also calculates an equivalent uniform annual cost and an equivalent uniform annual cost per square yard. Inputs are similar to those of the ECON report; however, one major difference is that the analysis period used is the alternative's anticipated life. Since annual costs are compared, common lives of alternatives are not required; this

REPORT DATE - 85/03/05.

COMPARISON OF M&R ALTERNATIVES
IVPAT-04
SECTION 04

INFLATION RATE 4.50 PERCENT
INTEREST RATE 10.00 PERCENT

ANALYSIS PERIOD - 20 YEARS

ALTERNATIVE	DESCRIPTION	NET PRESENT COST
A	OVERLAY	52440.
B	RECONSTRUCTION	81498.

DETAILED COMPARISON OF M&R ALTERNATIVES

YEAR	ALT A COST	ALT A PRES COST	ALT B COST	ALT B PRES COST
0 (FY85)	32027	32027	79662	79662
1 (FY86)	0	0	0	0
2 (FY87)	0	0	0	0
3 (FY88)	0	0	0	0
4 (FY89)	0	0	0	0
5 (FY90)	1000	773	1000	773
6 (FY91)	0	0	0	0
7 (FY92)	0	0	0	0
8 (FY93)	0	0	0	0
9 (FY94)	0	0	0	0
10 (FY95)	32027	19175	1000	598
11 (FY96)	0	0	0	0
12 (FY97)	0	0	0	0
13 (FY98)	0	0	0	0
14 (FY99)	0	0	0	0
15 (FY00)	1000	463	1000	463
16 (FY01)	0	0	0	0
17 (FY02)	0	0	0	0
18 (FY03)	0	0	0	0
19 (FY04)	0	0	0	0
20 (FY05)	0	0	0	0
TOTAL	66054	52439	82662	81497
SALVAGE	0	0	0	0
PRES WORTH		52439		81497

Figure 58. Economic analysis (ECON) report.

difference generally makes use of the ECON 1 report preferable. Also, results of the ECON 1 report can be fed directly into the BUDOPT report. Figure 59 illustrates the ECON 1 report.

Selecting the Most Feasible Alternative

Comparing Alternatives

Once a life-cycle cost analysis has been performed on each feasible alternative for a given pavement section, the one with the lowest life-cycle cost should become the most favored alternative. By using the lowest life-cycle cost as a decision variable, the user will gain an important management benefit of having pavement sections adequately repaired while minimizing the overall cost. (This same philosophy led to the section being selected for repair, so it is consistent that cost be used as a criterion for selecting the most feasible alternative.)

As discussed in Chapter 3, the BUDOPT report can be used at the network level to select candidate sections for repair. This same report can also be used at the project level to select the most feasible repair alternatives. Recall that the repair project being considered probably encompasses more than one pavement section. For each of these sections, several repair alternatives have been considered and an economic analysis performed. Also, for a given repair project, it is likely that a budget has been fenced around the project. The BUDOPT report will select the best alternatives based on optimizing an incremental benefit/cost ratio for a given budget.

To use the report for this purpose, a benefit analysis must first be performed on each alternative. (Procedures for doing a benefit analysis were described in Chapter 3.) The benefit analysis will require the PCIs after repair for each alternative. This will be discussed later in this report.

The results of the benefit analysis and the ECON 1 report will be used as input information for the BUDOPT report. Figure 60 provides an example, and further discussion is available in the literature.[22]

Practical Considerations

Once the most feasible alternative for each pavement section in the repair project has been established, engineering judgment must once again be used to ensure that all practical considerations have been made and that the best repair will be done. It may not be practical to have a variety of repair types within the same project. If this has resulted, the user should consider having uniformity or at least similarity among the repair types on given sections. Since the sections were originally combined into a given repair project based partly on repair type, alternatives developed at the project level will very likely be similar for all the sections.

---

[22] M. Y. Shahin, S. D. Kohn, R. L. Lytton, and W. F. McFarland, "Pavement M & R Optimization Using the Incremental Benefit-Cost Technique," *North American Pavement Management Conference Proceedings*, Vol II (1985), pp 6.96 - 6.107.

```
DATE:=  85/03/05.      PROJECTED COST ANALYSIS          (DETAIL)

                      SECTION ID:=1VPAT-04
ALTERNATIVE:= RECONSTRUCTION                SECTION AREA(S.Y.):=      3905.0
LIFE OF ALTERNATIVE:= 20 INTEREST RATE:= 10.0   INFLATION RATE:=    4.5

M&R ACTIVITY               YEAR          COST(S)         PRESENT VALUE($)
ORIGINAL CONSTRUCTIO 1985           79662.00        79662.00
M&R                        1990           1000.00           773.78
M&R                        1995           1000.00           598.74
M&R                        2000           1000.00           463.29

INITIAL COST($):=                              79662.00
PRESENT VALUE($):=                             81497.81
EQUIVALENT UNIFORM ANNUAL COST($):=             9572.70
EUAC PER SQ. YD. ($):=                             2.45
               ------------ END OF REPORT -----------
SELECT:(A-F)     (H=HELP)
? E

DATE:=  85/03/05.      PROJECTED COST ANALYSIS          (DETAIL)

                      SECTION ID:=1VPAT-04
ALTERNATIVE:= OVERLAY                       SECTION AREA(S.Y.):=      3905.0
LIFE OF ALTERNATIVE:= 20 INTEREST RATE:= 10.0   INFLATION RATE:=    4.5

M&R ACTIVITY               YEAR          COST(S)         PRESENT VALUE($)
OVERLAY                    1985           32027.00        32027.00
M&R                        1990            1000.00          773.78
OVERLAY                    1995           32027.00        19175.75
M&R                        2000            1000.00          463.29

INITIAL COST($):=                              32027.00
PRESENT VALUE($):=                             52439.82
EQUIVALENT UNIFORM ANNUAL COST($):=             6159.56
EUAC PER SQ. YD. ($):=                             1.58
               ------------ END OF REPORT -----------
```

Figure 59. Economic analysis (ECON1) report with equivalent uniform annual cost.

INPUT DATA
****

LOC	ALT-NO	EUAC/SY	ANNUAL-BENEFIT	INITIAL-COST
1	1-1	2.10	32.00	24000.00
1	1-2	2.40	23.00	35000.00
1	1-3	4.10	47.00	85000.00
1	1-4	3.40	34.00	47000.00
2	2-1	3.50	43.00	43000.00
2	2-2	3.10	39.00	48500.00
2	2-3	2.90	45.00	55000.00

PROJECTS OF SAME TOTAL COST BUT LESS BENEFIT DELETED
****

LOC	ALT-NO	EUAC/SY	ANNUAL-BENEFIT	INITIAL-COST

NO PROJECT IS DELETED

AN INCREMENTAL BENEFIT-COST ANALYSIS
****

LOC	ALT-NO / INC COST	INITIAL-COST / INC BENEFIT	EUAL/SY / INC BC-RATIO	ANNUAL-BENEFIT / AVG BC-RATIO
1	1-1	24000.00	2.10	32.00
	2.10	32.00	15.24	.00
1	1-4	47000.00	3.40	34.00
	1.30	2.00	1.54	.00
1	1-3	85000.00	4.10	47.00
	.70	13.00	18.57	7.50
2	2-3	55000.00	2.90	45.00
	2.90	45.00	15.52	.00

Figure 60. Budget optimization (BUDOPT) report for alternative selection.

PROJECTS DELETED
****

LOC	ALT-NO	INITIAL-COST	EUAC/SY	ANNUAL BENEFIT	INC COST	INC BENEFIT	INC BC-RATIO
1	1-2	35000.00	2.40	23.00	.30	-9.00	-30.00
2	2-2	48500.00	3.10	39.00	.20	-6.00	-30.00
2	2-1	43000.00	3.50	43.00	.60	-2.00	-3.33

SELECTION OF PROJECTS
****

ALT-NO	INITIAL-COST	EUAC/SY	ANNUAL BENEFIT	INC COST	BC-RATIO	CUM COST
2-3	55000.00	2.90	45.00	2.90	15.52	55000.00
1-1	24000.00	2.10	32.00	2.10	15.24	79000.00
1-3	85000.00	4.10	47.00	2.00	7.50	140000.00
1-4	47000.00	3.40	34.00	1.30	1.54	-*

THE FOLLOWING BEST SOLUTION IS OBTAINED WHEN THE ONE TO ONE AND PAIRWISE PROJECT REPLACEMENT ARE NOT POSSIBLE.

THE PREFERED SOLUTION OF PROJECTS FOR A FIXED BUDGET OF 100000.00 IS :

ALT-NO	EUAC/SY	ANNUAL-BENEFIT	INITIAL-COST
1-1	2.10	32.00	24000.00
2-3	2.90	45.00	55000.00

THE TOTAL INITIAL COST IS 79000.00
THE TOTAL ANNUAL BENEFIT IS 77.00
THE EXCESS BUDGET IS 21000.00

$REVERT. *** END BUDOPT PROCEDURE ***

Figure 60 (Cont'd).

Final Design

The final stages of the project include final plans and specifications, contract package preparation (if applicable), and an "in-house" work order (if applicable). Procedures should follow those normally used at the installation, and very little interface will probably be needed with the PAVER database. If more information is needed to complete the design, the appropriate PAVER report can be run and the information obtained.

Detailed Localized Maintenance and Repair Analysis

It is often desirable to perform a project-level evaluation on a pavement section that is only to receive maintenance, localized repair, or major repair where the PCI will not go to 100. A series of reports in PAVER allows this analysis to be performed. These are the Distress Prediction (PREDICT) report, the Analysis of Localized Repairs (ANALOC) report, and the Consequences of Local Repair (CONLOC) report. The development of these reports is provided in ESL-TR-81-19.

Predicting Distresses

The engineer must often face hard choices about what work to perform and what work to defer. At the network level, this is addressed in terms of PCI. At the project level, there is more concern about the appearance and growth of various distress types. For example, an engineer may know that in a given pavement section, a certain amount of low-severity alligator cracking is present. If no maintenance is performed to correct that situation, the engineer may want to know how soon and how much medium-severity alligator cracking will form and to what extent the low-severity alligator cracking will spread. Estimating what will occur and when it will occur can be of great value in planning maintenance or repair activities. The PREDICT report is used in this analysis. It requires the results of the INSPCUR, previous INSPECT reports (if available), SPECIFY, or LOOK reports and the pavement age since construction or last overlay. The percent severity displayed in the report is the amount of distress in future years. Figure 61 shows an example output.

PCI After Repair

When a pavement section is maintained or locally repaired, the section's PCI will usually increase. However, it will almost always be less than 100 because maintenance or localized repair seldom eliminates all distress in the section. The ANALOC report can be used to determine PCI after repair. This report, which accesses the database, uses the results from the last pavement inspection to determine the PCI and the types, severities, and amounts of distress present in the section.

The user can run an MRG report as a portion of the ANALOC report; this will match up the existing maintenance policy with the distresses found at the last inspection. It will also provide the cost of repairing certain distress types. In using the MRG portion of the report, the user is also given the opportunity to change the maintenance policy on a temporary (one-time) or permanent basis.

In continuing with the ANALOC analysis, the user can then decide which distresses to repair. This is done interactively at the terminal, and depending on the specific maintenance or repair to be performed on given distresses, PAVER will calculate a revised PCI after repair. The logic behind this analysis is that, for example, if alligator

```
                         DISTRESS INPUT DATA

        DISTRESS TYPE =       1.
        AGE          =   15.00  YEARS
        L            =   15.78
        M            =   11.65
        H            =    4.58
        EARLIEST DISTRESS STARTING TIME =     8.0   YEARS
        LATEST DISTRESS STARTING TIME   =    12.0   YEARS
        DISTRESS AT INITIAL TIME =    .1000
        EARLIEST TIME FROM L TO M       =     2.0   YEARS
        LATEST TIME FROM L TO M         =     4.0   YEARS
        EARLIEST TIME FROM M TO H       =     3.0   YEARS
        LATEST TIME FROM M TO H         =     5.0   YEARS
        MAXIMUM PREDICTION AGE          =    40.0   YEARS

          OPTIMUM VALUES
               INITIAL TIME      =        8.0  YEARS
               TIME FROM L TO M =          2  YEARS
               TIME FROM M TO H =          3  YEARS
                    MEAN                =   16.2449   YEARS
                    STANDARD DEVIATION =     2.6629   YEARS
```

YEAR	L+M+H	L	M	H
8	.10	.10	0.00	0.00
9	.33	.33	0.00	0.00
10	.95	.85	.10	0.00
11	2.45	2.12	.33	0.00
12	5.55	4.60	.95	0.00
13	11.15	8.71	2.35	.10
14	19.96	14.41	5.22	.33
15	32.01	20.86	10.20	.95
16	46.34	26.38	17.52	2.45
17	61.16	29.15	26.46	5.55
18	74.50	28.17	35.19	11.15
19	84.96	23.80	41.20	19.96
20	92.07	17.57	42.49	32.01
21	96.29	11.33	38.62	46.34
22	98.46	6.39	30.91	61.16
23	99.44	3.15	21.79	74.50
24	99.82	1.35	13.51	84.96
25	99.95	.51	7.37	92.07
26	99.99	.17	3.53	96.29
27	100.00	.05	1.48	98.46
28	100.00	.01	.55	99.44
29	100.00	.00	.18	99.82
30	100.00	.00	.05	99.95
31	100.00	.00	.01	99.99
32	100.00	.00	.00	100.00
33	100.00	.00	.00	100.00
34	100.00	.00	.00	100.00
35	100.00	.00	.00	100.00
36	100.00	.00	.00	100.00
37	100.00	0.00	.00	100.00
38	100.00	0.00	.00	100.00
39	100.00	0.00	.00	100.00
40	100.00	0.00	0.00	100.00

```
          END OF LOOP ON DISTRESS TYPE          1.

$REVERT. *** END PREDICT PROCEDURE ***
/
```

Figure 61. Distress prediction (PREDICT) report.

cracking is to be patched, the computer will eliminate alligator cracking as a distress, substitute a low-severity patch, and adjust the PCI accordingly. The ANALOC report does have default values for what the existing distresses will be modified to if they are repaired, but again, the user can make appropriate changes. In using this report, the engineer can see the results in terms of PCI gain and distress modification if certain maintenance or repair procedures are done. He/she must exercise judgment about whether the PCI gain and distress modification are worth the cost of the maintenance or repair. The user is cautioned that the ANALOC report is a relatively expensive report to run. Therefore, it is recommended that this report not be used indiscriminately, but used only where appropriate. Figure 62 illustrates the ANALOC report.

Consequences of Local Repair

The CONLOC report predicts the PCI that will occur after a repair has been performed. This is an interactive report that does not interface with the PAVER database. Inputs consist of age and PCI information. The PCI immediately after repair will either be 100 or can be obtained from the results of the ANALOC report. Current and previous PCIs can be obtained from INSPEC reports. Figure 63 illustrates the CONLOC report.

Preventive Maintenance Analysis

Preventive maintenance will not greatly increase the PCI, but if administered properly, it will slow the deterioration rate. In the long run, this will be beneficial. Figure 64 illustrates the benefits of a preventive maintenance program as opposed to waiting until overall repairs are required. Figure 65 represents the total amount of money spent as a result of preventive maintenance versus the repair-as-needed strategy. In many cases, several preventive maintenance activities will be more economical than one major repair project for a section. This will result in a pavement that is in better condition at a very economical cost.

Preventive maintenance activities can be analyzed with the CNDHIST report. Over time, this report will graphically illustrate the deterioration rates on a given pavement section. If inspections are performed relatively soon after the maintenance is done, the user will be able to track the rate of deterioration from that point. From there, he/she can see if the rate is changing, and if so, how much. Over time, the condition history plot should resemble the one shown in Figure 66 and can be used to analyze the effectiveness of the programs.

Project Management of Nonstandard Pavements

Most of the detailed project-level analysis work and alternative formulation discussed in this chapter can be performed on nonstandard pavements. A major difference will be that there will not be any inspection data within the database and that PCIs cannot be used. However, use of the economic analysis and determination of feasible alternatives will be the same.

Feedback

The same information on feedback given for the network level also applies at the project level. There must be communication between pavement inspectors, planners, and designers. Feedback to designers will provide them with information about how well the

PCI AFTER REPAIR REPORT

DATE SURVEYED 2/10/84. BRANCH IVPAT SECTION 04

PCI OF BRANCH AFTER REPAIR = 68 RATING = GOOD

EXTRAPOLATED DISTRESS QUANTITIES FOR SECTION

DISTRESS-TYPE	SEVERITY	QUANTITY	DENSITY-PCT	DEDUCT VALUE
1 ALLIGATOR CR	LOW	[illegible]59 SF	2.73	19.1
3 BLOCK CR	L[illegible]	[illegible]972 SF	11.30	9.1
3 BLOCK CR	[illegible]	3451 SF	9.82	15.8
6 DEPRESSION	LOW	639 SF	1.82	4.8
7 EDGE CR	LOW	304 LF	.86	2.8
10 L & T CR	LOW	564 LF	1.60	3.9
11 PATCH/UT CUT	LOW	3147 SF	8.95	15.0

*** PERCENT OF DEDUCT VALUES BASED ON DISTRESS MECHANISM ***

LOAD	RELATED DISTRESSES =	31.10 PERCENT DEDUCT VALUES.
CLIMATE/DURABILITY	RELATED DISTRESSES =	40.87 PERCENT DEDUCT VALUES.
OTHER	RELATED DISTRESSES =	28.03 PERCENT DEDUCT VALUES.

Figure 62. Analysis of localized repair (ANALOC) report.

```
DATE:=  85/03/05.           CONSEQUENCE OF LOCALIZED REPAIR
                               BRANCH NUMBER:= PBCNE
PRESENT PCI:=     54
    AGE SINCE LOCALIZED
    MAINTENANCE APPLIED           PROJECTED PCI
            0                          90
            5                          73
           10                          57
           15                          40
           20                          24
SELECT(A-E):
? D

DATE:=  85/03/05.           CONSEQUENCE OF LOCALIZED REPAIR
                               BRANCH NUMBER:= PBCNE
PRESENT PCI:=     54
    DO NOTHING ALTERNATIVE
    PREDICTION AGES                 PROJECTED PCI
            0                          54
            5                          37
           10                          21
           15                           4
           20                           0
```

Figure 63. Consequences of localized repair (CONLOC) report.

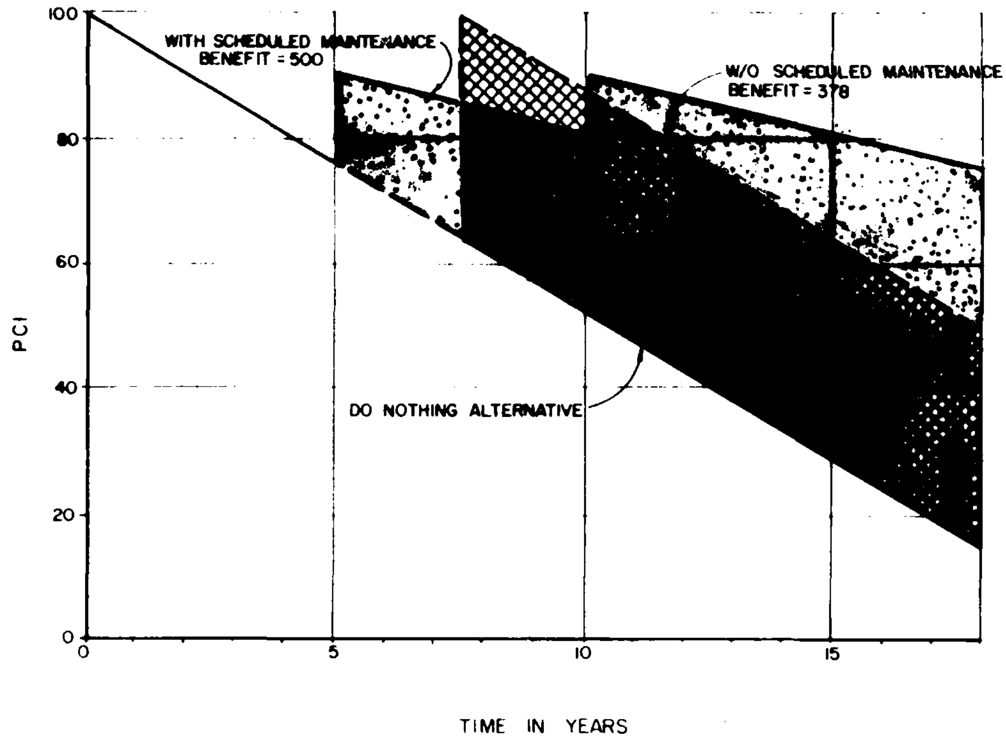

Figure 64. Example benefits of a preventive maintenance program.

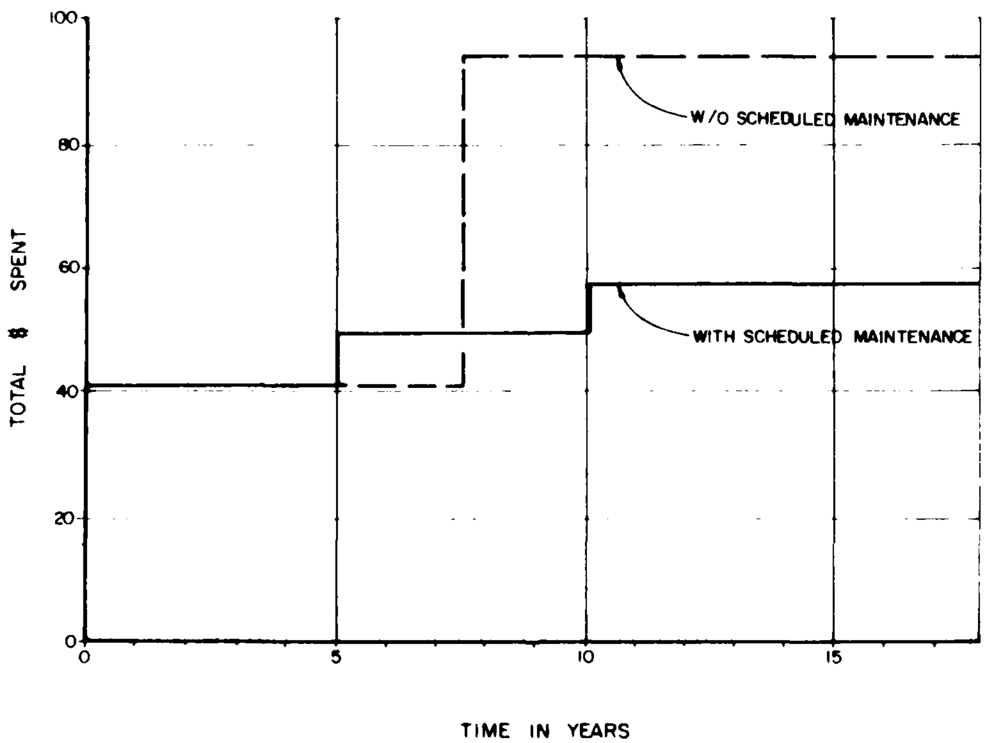

Figure 65. Example funds expenditure versus strategy.

pavements are actually performing. If there are recurring problems, future designs should be modified accordingly. Feedback between planners and designers will provide the planners with key design information to be used in the preliminary repair strategies developed at the network level.

Updated cost information for both contracts and in-house work will be of great value to both planners and designers in estimating project costs.

Reports from construction inspectors can provide useful information about the actual construction materials, methods, and problems encountered on the job. This feedback can be of great value to designers for preparing future designs.

User complaints can also be an important form of feedback. Comments will provide important operational condition indicators and can be useful in future designs.

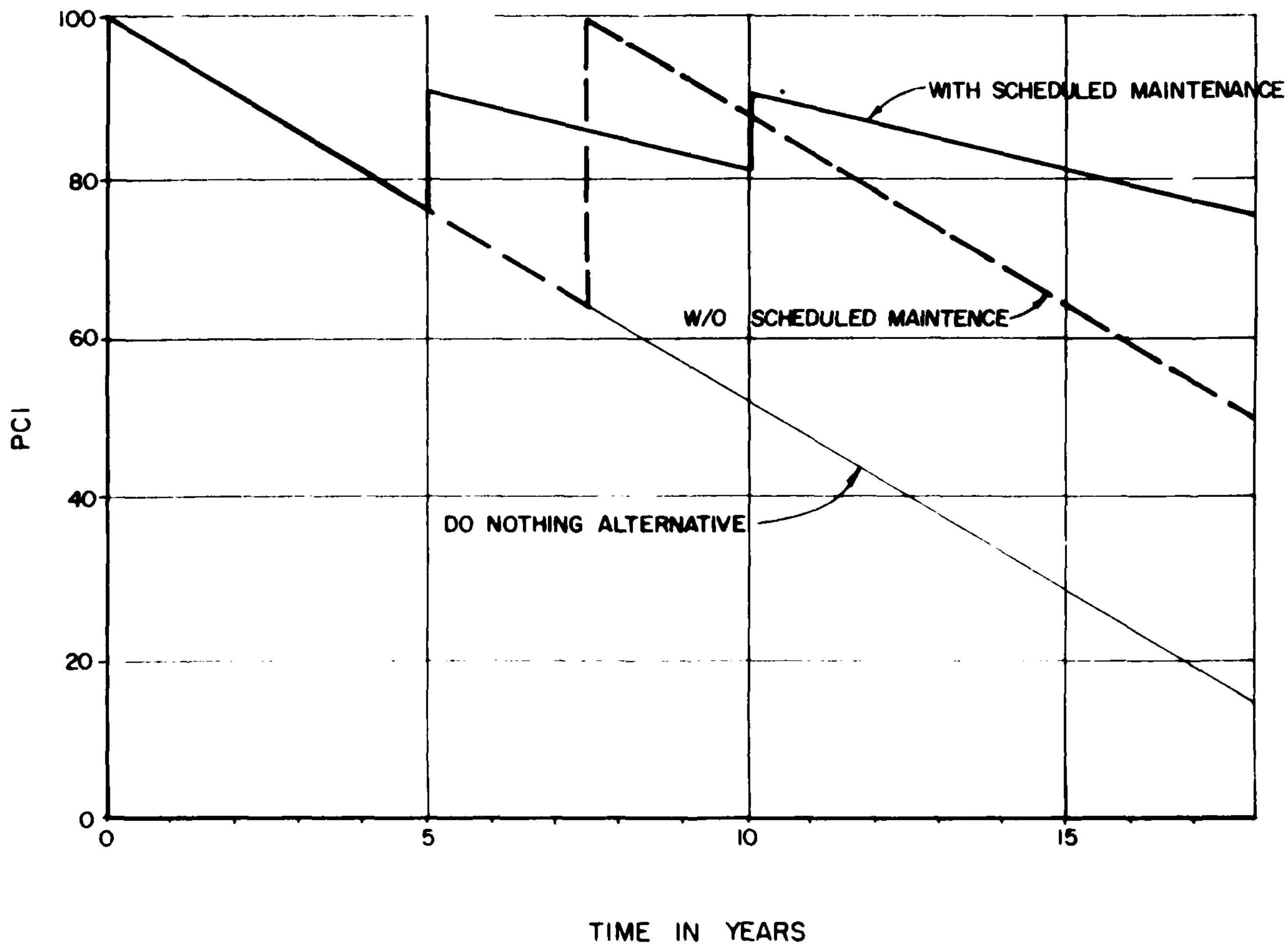

Figure 66. Example condition history for a pavement section.

5 DATABASE UPDATE

Various data elements must be updated periodically for PAVER to remain a viable decision support system. This is because the pavement network itself and the costs associated with maintaining and repairing that network are dynamic. Information that becomes obsolete can lead to erroneous and misinformed decisions, which negates the system's positive effects.

The *PAVER User's Guide* provides the actual mechanics for completing data entry forms and for the data loading procedures.

Cost Information

Cost information is used in the decision-making process. It is used for project selection, budgeting, maintenance and repair planning, and in work plan and construction contract preparation. The need for accurate cost information cannot be overstated. Erroneous cost information can lead to improper funding of projects, thereby leading to less than optimum repairs or deferral of planned work to future years.

Updated cost information should be compiled annually. These data should be compiled primarily from construction bid prices and engineers' estimates based on the latest estimating guides. The updated data should be assembled prior to budgeting and project planning during the annual cycle. Items that will require update include the maintenance and repair policy, the PCI cost curves, and any associated overall repair costs that would be used when doing tentative designs at the project level.

Maintenance and Repair Policy Costs

The POLICY report (Figure 37) should be run annually and the unit costs studied as to their current applicability. Unit costs for work to be performed in-house should be based on shop and labor rates that will apply for the upcoming construction season. Unit prices for contract work for requirements or recurring services should be based on the prices set forth in the contract or based on standard procedures for construction contracts.

PCI Versus Cost Curves

PCI versus cost curves, as discussed in Chapter 3, should be developed annually. The latest bid information and/or construction cost-estimating guides can be used to estimate major repairs. Maintenance costs should use the updated costs in the POLICY report.

Work Requirements

When work is planned at the network or project level, the results should be entered in the database. When the work planned for a given section is revised, the database should be updated to reflect the changes. These changes will most likely result from project refinements as a section is reanalyzed at the project level or from additional needs resulting from deferred work.

Work Completed

Each year, as projects are completed, the results must be added to the database in the work history file. This will include results for both major repair and maintenance projects.

Information for both major repair and maintenance projects will be input in the same way. For major repair projects, the user must use the work code that best describes the work performed. Maintenance project updates pertain to a specific work type and distress type. Completed input should include any work performed on or around the section. This will also apply to nonstandard pavements.

Certain work types, such as reconstruction, overlay, and surface treatment, and other types in which the pavement structure is altered will also require the pavement structure file to be updated. In addition, the date of last overlay or construction must be updated in the section identification file. If any work includes changes to shoulders, drainage, or secondary structures, those data files should be updated too. The database will also accept comments, which can be input any time a short narrative is felt to be appropriate.

If the completed work matches what is listed in the work requirements (WORKREQ) file, then the work requirement file can easily be tranferred into a work history (WORKHIS) data file, thereby saving effort in recoding and entering data.

The more information that can be added to the database, the more useful and reliable the data will be in future years. This will allow the user to track the history of work performed on the section. This will be of great value to the engineer in drawing up future tentative designs for the section.

Updating Section Condition Information After Work Completion

Major repairs such as overlay or reconstruction, which return the pavement section to an essentially new condition, will require that PCIs be changed to 100. If the date of last overlay or construction has been updated in the database, then the PCIs will automatically revert to 100 for use with the CNDHIST and FREQ reports. A second method would be to input the result of a dummy inspection using the date of repair as the inspection date. There will be no distress, thereby giving PCIs of 100.

For maintenance or localized repairs in which PCI will not return to 100, the new PCIs can be entered into the database in two different ways. One method would be to use the ANALOC report, which will give the estimated PCI after repair and a listing of distress types, severity, and amounts of distress remaining after the repairs have been finished. These can be re-entered into the database using a dummy inspection method. The second method would be to actually go out and inspect the pavement after the repairs or maintenance have been done. The inspection can be any time after the work is completed, but it should be done within one year of work performance. If a pavement section has been maintained or repaired and is scheduled for a routine inspection within a year, the routine inspection will provide adequate documentation.

Any time dummy inspections are used to reflect pavement condition, a comment should be inserted to reflect the fact that this was a dummy inspection, not an actual inspection.

New Construction or Geometric Alterations to Existing Sections

If new sections are built, or if existing sections are revised geometrically, these must be added to the database in accordance with the same process used in the original implementation.

Modifying Sections

Occasionally, a pavement section should be subdivided into two or more sections. Also, it may sometimes be prudent to combine two or more pavement sections into one section. This should be considered any time the parameters used in the original section identification have been altered significantly.

If the engineer feels a pavement section lacks uniformity due to changes in traffic or work completed, he/she should consider dividing the section into two or more sections. This can be done easily. The original section identification must first be revised to reflect the smaller area. A new section identification will be created for the new area just as if a brand new section were being entered into the database. Note, however, that other data elements may also have to be revised. These would include drainage, shoulders, secondary structure, pavement structure, and so forth.

When subdividing sections, particular care should be taken in assigning a section number. For example, if section 02 of a branch is to be divided into two portions, one of them should remain section 02. The "new" section (between sections 02 and 03) could be called section 2A. This keeps the numbering continuity intact, and would tell a user that section 2A was once part of section 02.

Combining two or more sections into one pavement section is a bit more difficult. This should be considered if the user believes two or more adjacent sections are essentially uniform and are being managed as essentially one section. This can also result from changes such as traffic and work completed. If combining is to be done, one section will have to be expanded and the sections that are no longer needed will have to be deleted. However, the user is cautioned that whenever a section is deleted from the database, all work history, inspection information, etc., will be purged. Therefore, careful consideration should be given before sections are deleted.

Other Pertinent Data

Any data the user feels is useful should be added to the PAVER database. There is essentially unlimited capacity for this information, especially under the category of secondary structures. However, the user is cautioned that it is possible to go overboard if large amounts of unnecessary data are collected and stored. It is recommended that data considered to be unnecessary in the pavement management process be scrutinized very carefully before adding them to the database.

6 MISCELLANEOUS PAVER USE

Value of the PAVER Database

PAVER does not have to be limited to the uses described in Chapters 2 through 5. The uses of the database are virtually unlimited, requiring only that the proper data be input in a form the PAVER database can accept and use in its different reports.

Potential Uses of PAVER

Any project or study involving the installation road network can be enhanced with data available from the PAVER database.

Traffic Pattern Studies

Traffic distribution and traffic patterns can be developed and analyzed for an installation by using traffic data from the database and any other available information. Since each pavement section has a uniform traffic volume and mix, the user can estimate traffic flows from on and off various streets; flow can also be estimated using information from other traffic studies.

Utility Line Trenching Through Pavement

The amount of utility trenching can often become excessive in certain areas and cause severe problems. Also, the location of underground utilities will be very important in any type of reconstruction. When a utility trench is cut in a pavement, the type of utility and approximate location of the trench can be recorded and stored in the database. This information would be useful in the future when the need to locate underground utilities may become important. Also, in planning for the trenching work, the PAVER database can be used to determine the pavement structure so that it is known what kind of pavement needs to be cut through and the kind of patch needed to complete the work.

Drainage Studies

PAVER can provide information about the location and type of drainage structures and the length and approximate size of roadside ditches. Along with area topographic maps, the general drainage distribution, capacity, and problem areas can be identified for more in-depth analysis.

7 SUMMARY

This report has provided information to aid personnel in the practical use of PAVER to plan, program, budget, and develop projects. Outlined were field-tested, step-by-step procedures for successfully implementing PAVER, managing the pavement network as a whole, and doing in-depth project-level analysis of specific pavement sections. The procedures have been presented in the actual sequence an engineer could expect to use them in the field.

The development of PAVER is not complete. Research is currently under way to further improve and enhance the system's capabilities. Examples include the development of a condition index for gravel roads, a systematic but simplified method for computing the PCI versus cost curves at a given installation, and the development of consequence models for predicting the performance life of pavement sections once major repairs have been completed.

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APPENDIX A:

PAVER OUTLINE

```
******* PROCEDURE OUTLINE TO RUN PAVER ******

PAVER PROVIDES THE USER WITH THE FOLLOWING:
   A. ENTERING DATA INTO THE DATABASE.
   B. REPORTING.
   C. DATABASE  LOAD/UNLOAD/LOOK
   D. DATABASE SELECTOR
   E. REMARKS TO PAVER ADMINISTRATOR
   F. USER HELP FACILITY
   G. PERSONAL COMPUTER SOFTWARE

A. ENTERING DATA INTO THE DATABASE USES THE FOLLOWING PROCEDURES:
   1. BEGIN,EDIT,PAVER     - ENTER FIELD DATA FROM THE FORM-ID CHARTS.
   2. BEGIN,UPDATE,PAVER   - TRANSFERS EDIT DATA TO DATABASE(INCLUDING NDT DATA).
   3. BEGIN,RESULTS,PAVER  - DISPLAYS RESULTS OF THE DATABASE UPDATE.
   4. BEGIN,ERRORS,PAVER   - DISPLAYS ANY ERRORS INCURRED DURING UPDATE
                             OF THE DATABASE.
   5. BEGIN,BATCHIN,PAVER  - PROCESSES DATAFL FOR BATCH UPDATES.
   6. BEGIN,BATCNDT,PAVER  - PROCESSES DATANDT FOR BATCH UPDATES OF NDT DATA.
   7. BEGIN,EDITERR,PAVER  - LISTS THE ERROR FILE AFTER THE
                             BEGIN,BATCHIN,PAVER PROCEDURE.
   8. BEGIN,NDTERR,PAVER   - LISTS THE ERROR FILE AFTER THE
                             BEGIN,BATCNDT,PAVER PROCEDURE.
   9. BEGIN,CLEANUP,PAVER  - REMOVES THE UPDATE RESULTS/ERROR FILES
                             FROM YOUR CATALOGUE.

B. REPORTING USES THE FOLLOWING PROCEDURES:
   1. BEGIN,BATCH,REPORT  - ALLOWS INTERACTIVE OR BATCH PROCESSING
                            OF THE FOLLOWING REPORTS:

          REPORT --->    LIST    - LIST OF BRANCHES
                         INV     - INVENTORY OF PAVEMENT SECTIONS
                         INSPECT - SUMMARY OF PCI & DISTRESS
                                   INFORMATION FOR PAVEMENT SECTIONS
                         SAMPLE  - DETAILED SUMMARY FOR PCI & DISTRESS
                                   INFORMATION FOR PAVEMENT SECTIONS
                         WORKREQ - WORK REQUIREMENTS FOR PAVEMENT
                                   SECTIONS
                         WORKHIS - PAST WORK PERFORMED ON
                                   PAVEMENT SECTIONS
                         RECORD  - NON-INSPECTION DATA ON
                                   PAVEMENT SECTIONS
                         POLICY  - DISTRESS MAINTENANCE POLICY
```

```
PCI      - LIST OF SECTION PCI'S RANKED
           BY PCI (LOW TO HIGH)
PCIA     - LIST OF SECTION PCI'S IN
           ALPHABETICAL ORDER
INSPCUR  - SUMMARY OF LATEST PCI & DISTRESS
           INFORMATION FOR PAVEMENT SECTIONS
SAMPCUR  - DETAILED SUMMARY OF LATEST PCI &
           DISTRESS INFORMATION FOR PAVEMENT
           SECTIONS

---->  (BATCH PROCESSING ONLY)
FREQ     - PCI FREQUENCY
BUDPLAN  - BUDGET PLANNING
SCHED    - INSPECTION SCHEDULE
CNDHIST  - PCI HISTORY FOR A SECTION
MRG      - M & R GUIDELINES
           LOCALIZED REPAIR & OVERLAY
           COST FOR A SECTION
```

```
2. BEGIN,SPECIFY,REPORT     - SELECT WHICH DATA ITEMS TO REPORT
                              (BATCH OR INTERACTIVE)
3. BEGIN,RESULTS,REPORT     - DISPLAYS THE REPORT RESULTS IF BATCH
                              MODE WAS SELECTED FOR REPORT PROCESSING.
4. DATA ANALYSIS PROGRAMS   - ALLOWS INTERACTIVE USE OF THE
                              FOLLOWING DATA ANALYSIS PROGRAMS. THESE
                              PROGRAMS WITH THE EXCEPTION OF ANALOC
                              DO NOT ACCESS THE DATABASE.
     BEGIN,ECON,REPORT      - ECONOMIC ANALYSIS REPORT.
     BEGIN,ECON1,REPORT     - ECONOMIC ANALYSIS REPORT WITH UNIFORM
                              ANNUAL COST.
     BEGIN,VOL7,REPORT      - PCI PREDICTION OF AIRFIELD PAVEMENTS.
     BEGIN,PREDICT,REPORT   - PREDICTION OF INDIVIDUAL DISTRESSES.
     BEGIN,EVAL,REPORT      - RECOMMENDED FEASIBLE ALTERNATIVES FOR AIRFIELDS
     BEGIN,CONLOC,REPORT    - CONSEQUENCE OF LOCALIZED REPAIR
     BEGIN,BENEFIT,REPORT   - BENEFIT ANALYSIS FOR AIRFIELDS
     BEGIN,BUDOPT,REPORT    - BUDGET OPTIMIZATION
     BEGIN,ANALOC,REPORT    - ANALYSIS OF LOCALIZED REPAIR,
                              PCI AFTER REPAIR REPORT AND MRG REPORT
     BEGIN,PCICALC,REPORT   - CALCULATES PCI FROM DATA ON FILE TAPE70
                              WITHOUT ENTERING THE DATA INTO THE DATA BASE.
     BEGIN,PCICHEC,REPORT   - CHECKS TAPE70 FOR FORMAT ERRORS.
     BEGIN,PCIRES,REPORT    - PRINTS RESULTS FROM PCICALC.

C. LOAD/UNLOAD DATABASE
   1. BEGIN,LOAD,PAVER      - BRING DATABASE ON LINE.
   2. BEGIN,UNLOAD,PAVER    - TAKE DATABASE OFF LINE.
   3. BEGIN,LOOK,PAVER      - IMMEDIATE ACCESS TO DATABASE CONTENTS
```

```
D. BEGIN,SELECT,PAVER          - ALLOWS FOR SAVING AND RESTORING OF
                                 VARIOUS DATABASES.

E. REMARKS TO PAVER AUTHOR:
   1. BEGIN,REMARKS,PAVER      - SEND COMMENTS TO PAVER AUTHOR

F. USER HELP FACILITY:
   1. BEGIN,HELP,PAVER         - USER HELP MESSAGES.
   2. BEGIN,VRSION2,PAVER      - PROVIDES INFORMATION ON PAVER VERSION 2.0

G. PERSONAL COMPUTER SOFTWARE
   1. BEGIN,GETIBM,PAVER       - MAKES THE FOLLOWING IBM-PC PROGRAMS LOCAL FILES
                                 FOR DOWN LOADING TO YOUR IBM-PC.
        PAVERIN  - INPUT PAVER FORM-ID(S)
        EDITOR   - EDIT PAVER FORM-ID(S)
        REFORMT  - FORMAT DATA FOR UPLOADING TO CDC

   2. BEGIN,GETRS,PAVER        - MAKES THE FOLLOWING TRS-80 PROGRAMS LOCAL FILES
                                 FOR DOWN LOADING TO YOUR TRS-80.
        FIELD    - INPUT INSPECTION DATA (FORM-IDS 7-12) ONLY
        FIELDOC  - DOCUMENTATION
$REVERT. *** END PAVER OUTLINE ***
```

APPENDIX B:

IMPLEMENTATION CHECKLIST

1. Are the appropriate references (*PAVER, User's Guide: Paver Reference Manual: Pavement Maintenance Management*, TM 5-623; and *Airfield Pavement Evaluation Program*, AF Regulation 95-3) available?

2. Have they been read?

3. Has at least one key person attended a PAVER course?

4. Will the installation benefit from the implementation?

5. Has the decision been made to start?

6. Does the chain of command support the implementation?

7. Has a local User's Group been established?

8. Are the proper departments, divisions, and offices represented on the User's Group?

9. Has a chairman been designated?

10. Has FESA been notified of the impending implementation?

11. Have historical implementation costs been gathered?

12. Has a preliminary work plan been established?

13. Has the method of accomplishment been decided?

14. If the work will be done by contract, have guide specifications and sample contracts been obtained from FESA or others?

15. If the work will be done by contract, has a list of qualified contractors been obtained?

16. If the work will be done in-house, is a sufficient labor force available?

17. Have the implementation phases been established?

18. Have costs been estimated for each phase?

19. Is the first phase no more than 10 lane miles?

20. Has a steering committee been established?

21. Does a member of the User's Group serve on a steering committee?

22. Has a detailed work plan been established?

23. Has a rough estimate of the number of sections to be created been made?

24. Have zones been established?

25. Are section categories to be used?

26. Has a logical coding been established for zones and section categories?

27. Has a logical method of coding branch numbers been established?

28. Has it been established how sections and sample units will be marked in the field?

29. Will implemented sections be managed at the network or project level initially?

30. Has it been decided what data will be collected?

31. Do those data elements include, as a minimum, branch and section identification, an inspection, surface type, and date of construction or last overlay?

32. Is the type and amount of data to be collected consistent with management needs?

33. Are "as-built" drawings available?

34. Will a representative number of cores be required?

35. Has the appropriate number of sample units to be inspected been established?

36. Is a maintenance policy to be established?

37. Is a prioritization or optimization strategy to be created?

38. Has the computer terminal or microcomputer been obtained?

39. Has a modem been obtained?

40. Has the proper communications software been obtained?

41. Has a software package that permits batch loading of data been obtained?

42. Has a computer account been established with FESA?

43. Have the sections that are created been field-verified?

44. Have section identification records been prepared?

45. Has field data been checked for errors prior to entry into the database?

46. Have all remaining appropriate personnel been trained?

47. Once data has been entered into the database, has it been checked for errors?

48. Are sections that have been created too large or too small from a management perspective?

49. Are roadway intersections located in the proper sections?

50. Are section areas correct?

51. Are sample units sized correctly?

52. Have inspection results been at least spot-checked for accuracy?

53. Has the contractor, if appropriate, made all necessary corrections before the database is turned over to the government?

54. Have implementation problems encountered so far been documented and resolutions prepared for the remaining phases?

55. Have appropriate personnel had the opportunity to run PAVER reports to gain confidence?

56. Do appropriate personnel feel comfortable and confident in using PAVER?

57. Has PAVER been demonstrated to the steering committee?

58. Do appropriate personnel in the chain of command understand the capabilities of PAVER?

59. Has an office been designated as the PAVER residence?

60. Has a PAVER manager/coordinator been designated?

61. Are the PAVER access number and passwords safeguarded?

62. Is the edit password held by only the key personnel who must edit the database as part of their duties?

63. Are computer bills for time sharing reviewed for correctness?

64. For fullscale implementation, is the detailed work plan from No. 22 above, as modified to No. 54 above, being used?

65. Have station maps been prepared to reflect sectioning?

66. Are procedures established for updating the database, when needed?

67. Is it established that work completed and cost information will be updated into the database at least annually?

68. Has it been established when and how new pavements will be incorporated into the database?

69. Has it been established when and how removed pavements will be purged from the database?

70. Has management policy been established to properly use PAVER?

71. Is routine refresher training planned for inspectors and other personnel, as appropriate?

72. Has a policy been established for training new personnel, as appropriate?

73. Do personnel know who to contact when problems occur?

74. Are lines of communication open among the installation PAVER users?

75. Has the User's Group been retained and are periodic meetings planned?

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